Demonstrating Utility Partnerships for PV Integrated Storage

CSI RD&D Project Final Webinar

August 11, 2016

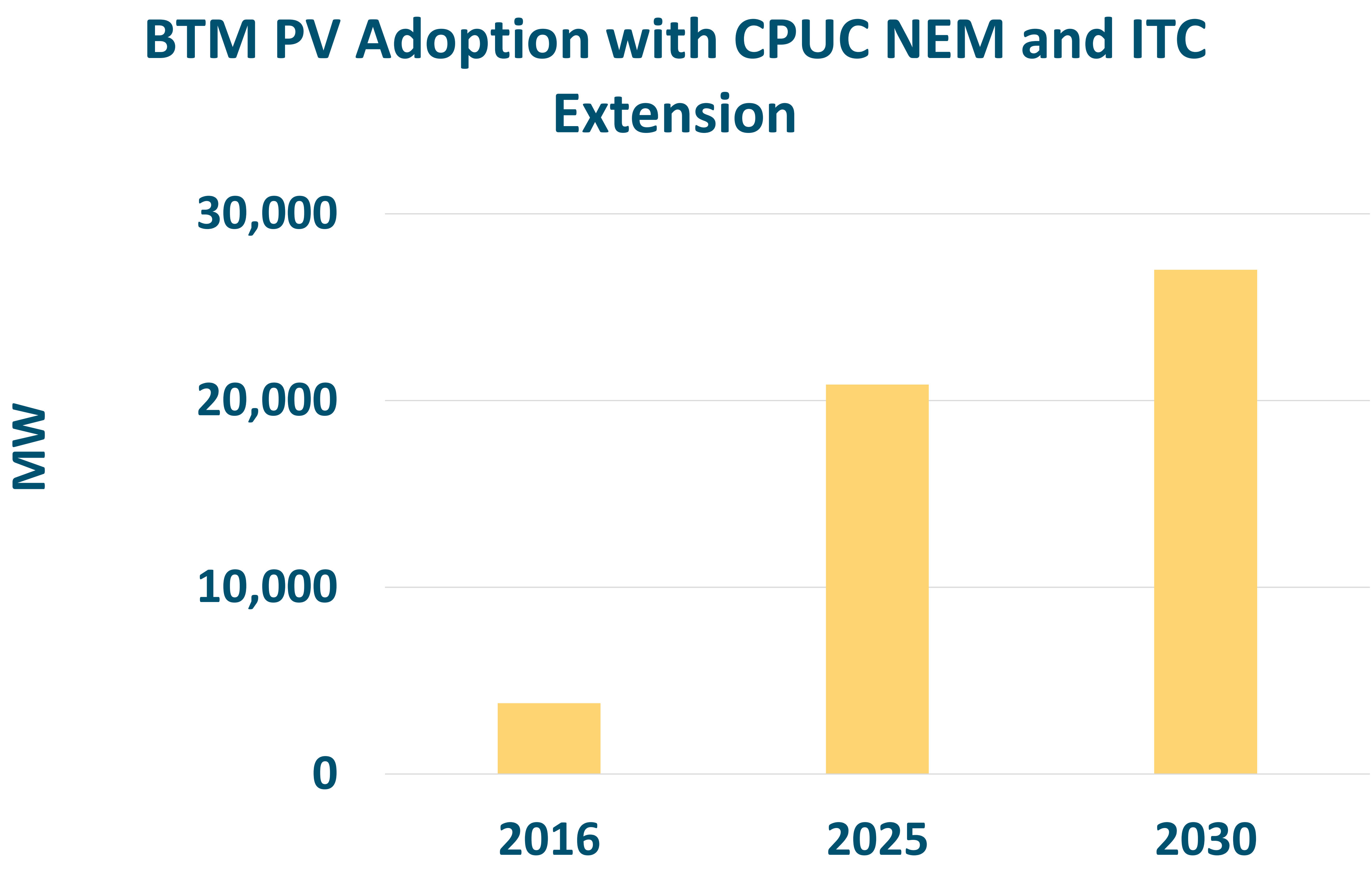
CSI RD&D Program Manager

Project Objectives

- Document storage performance with high resolution metering of 34 Sunverge PV integrated storage units at 2500 R Midtown Project in SMUD
- Demonstrate utility dispatch of customer-owned energy storage for customer and grid benefits
- Quantify local distribution system operational benefit support with OpenDSS power flow modeling
- Quantify benefits of utility dispatch of customer owned storage with Integrated Distributed Energy Resource (IDER) modeling
- Develop tariff, incentives and program designs recommendations

Policy Context

- Net Energy Metering (NEM) will continue to spur behind the meter (BTM) PV adoption
- AB 2514 requires CA IOUs to procure 1.3 GW of energy storage by 2020
- California Self Generation Incentive Program (SGIP) revised incentives for energy storage
- AB 327 requires investor owned utilities (IOUs) to incorporate DERs in distribution planning

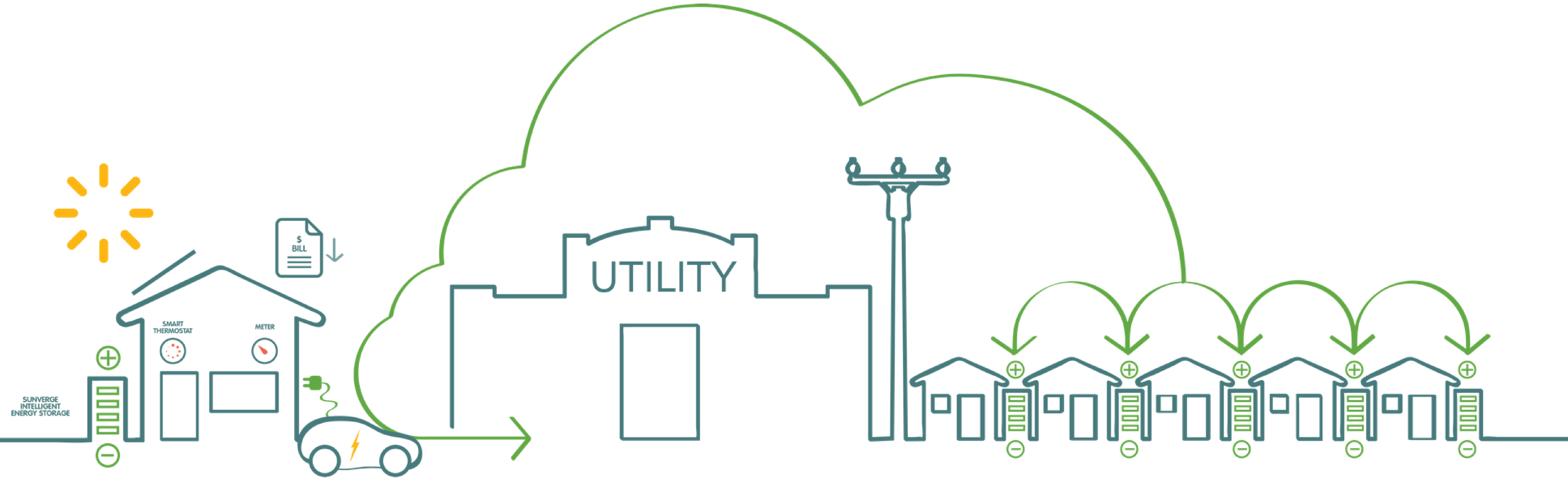


2025 non-NEM residential bill increases of $12-19 per month, or 13-21%

SUNVERGE

2500 R Midtown Storage + Solar Project

Eileen Hays-Schwantes, Program Manager



Company background

FOUNDED

2009

HEADQUARTERED IN

SAN FRANCISCO

SEED (2009)

1st DEVICE INSTALLED (2010)

SERIES A (2011)

SERIES C (2016)

52

EMPLOYEES

CUSTOMERS

North America (AZ, CA, HI, KY, NY, NV & Canada)
New Zealand
Australia
South Korea
Germany

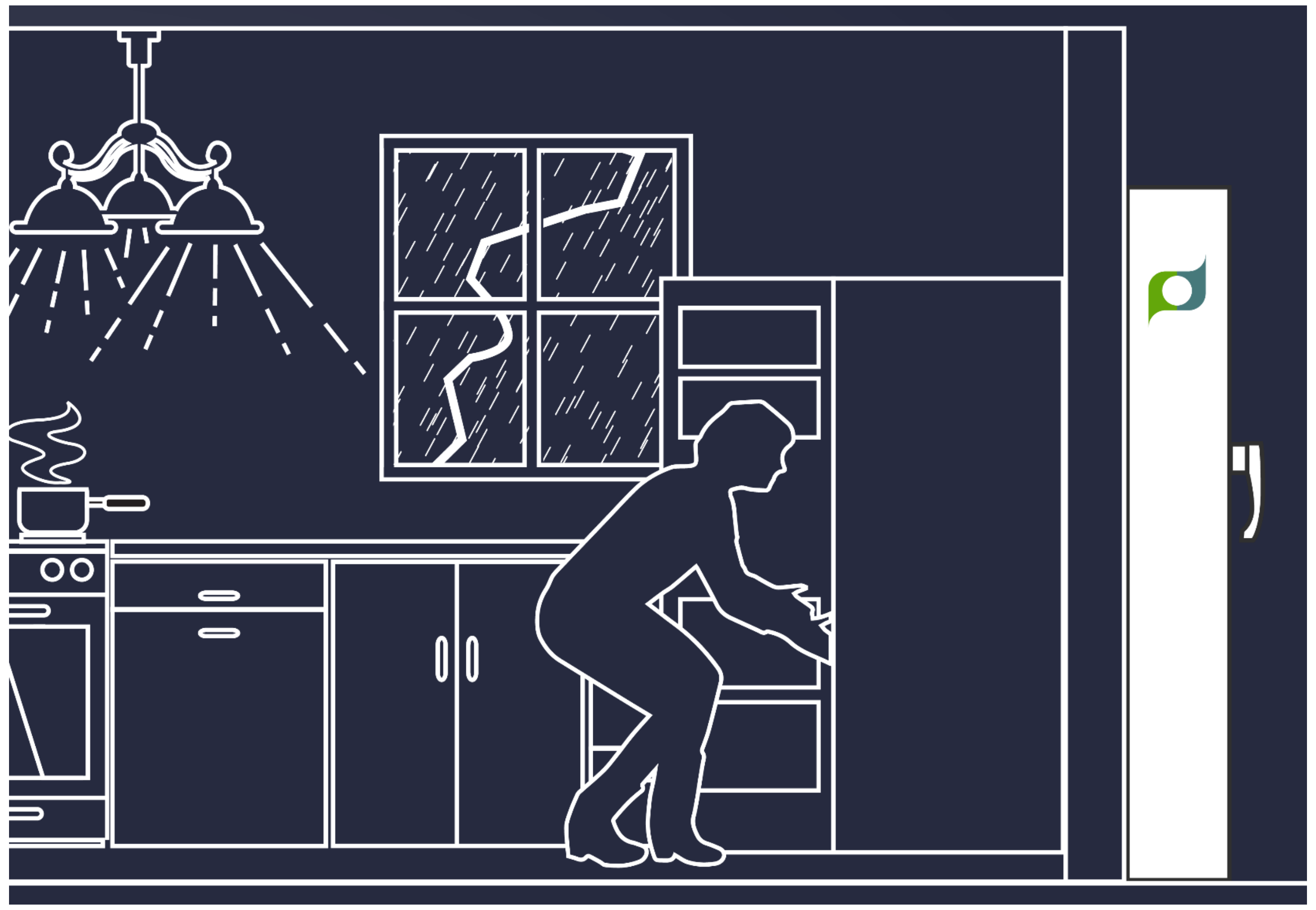
650

UNITS IN PRODUCTION AROUND THE WORLD

Sunverge Solar Integration System (SIS)

Sunverge Solar Integration System (SIS)

Storage Appliance + Renewable Power + Cloud Software



SUNVERGE

Hybrid Inverter
(4.5kW or 6kW rated)

IO Board

Solar Charge Controller
(150V or 600V MPPT)

Distribution Panel

Gateway Computer

NEMA 3R Enclosure

Lithium-ion Battery
(Scaleable to 19.4 kWh)

Polycrete pad

SUNVERGE

Case Study:
2500 R Midtown Project
Sacramento, CA

Affordable Housing Project & SMUD partnership

Sacramento, CA

PROJECT DESCRIPTION

34 new Net Energy Zero homes outfitted with:

- 4.5 kW inverter/150V MPPT/11.64 kWh Sunverge SIS
- 2.25 kW solar PV
- Smart thermostats and modlets

PROJECT GOALS

- Pilot Time-of-Use and Critical Peak Pricing rate tariff (1-R-SPO)
- Evaluate how high penetrations of renewables can yield maximum value through customer-sited energy storage

  2015 demonstration piloted and analyzed Virtual Power Plant capabilities for aggregating a storage fleet for distribution peak load shifting

- Provide reliable back-up power and bill reduction for homeowners

SMUD

SMUD®

Sacramento Municipal Utility District

Benefits and Performance

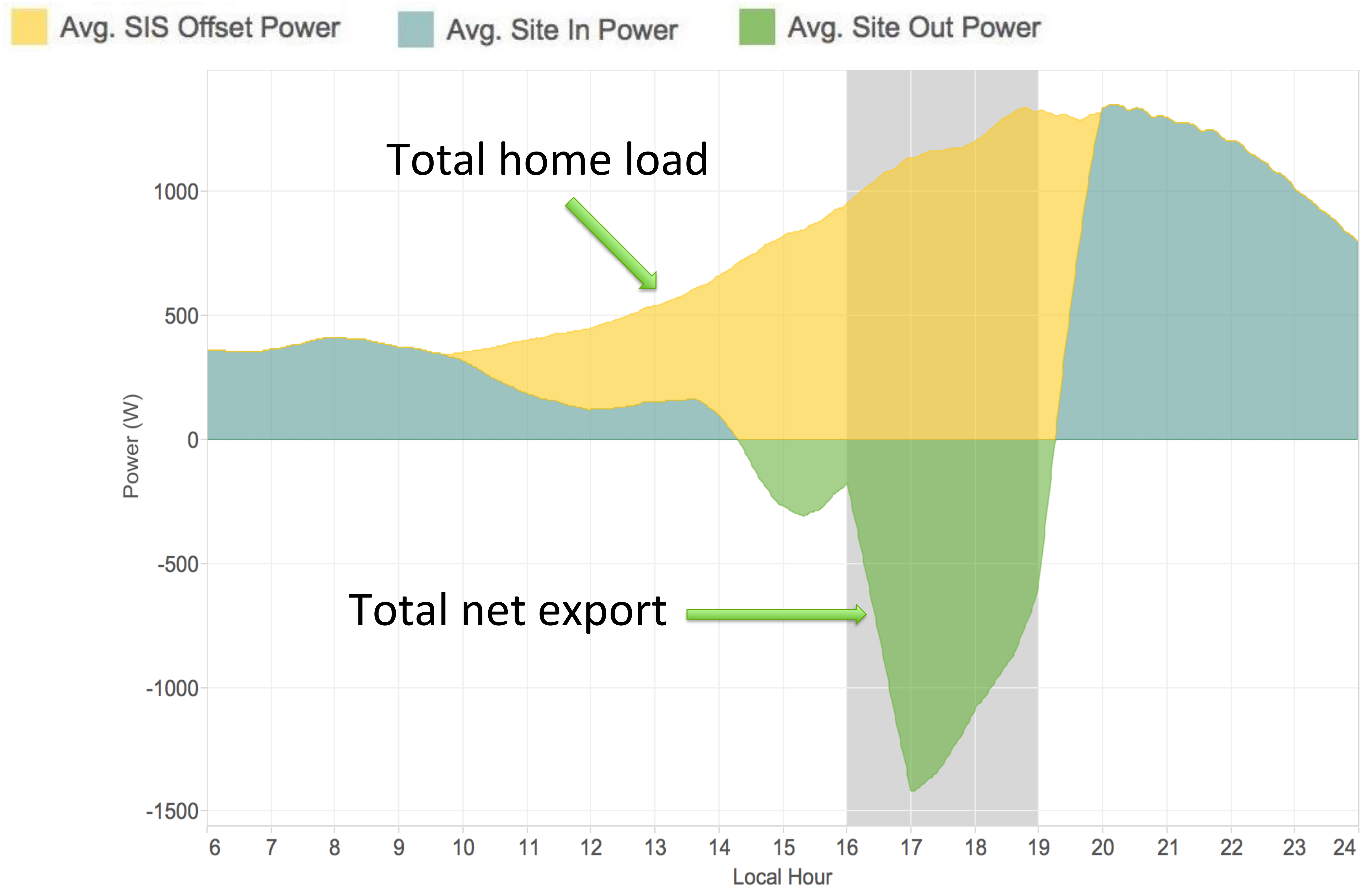
HOMEOWNERS

- Bill Savings
- Back-up Power

UTILITY

- Distributed energy resource aggregation with intelligent software controls to be used for grid management
    - Peak load reduction
    - PV export shifting
    - Load shaping for predictable dispatch
- Reliable energy supply - Improve during outages and demand reduction events
- DRMS integration - Integrate SMUD DRMS and Sunverge Control Software to dispatch a fleet of SIS units

DEMAND RESPONSE PERFORMANCE



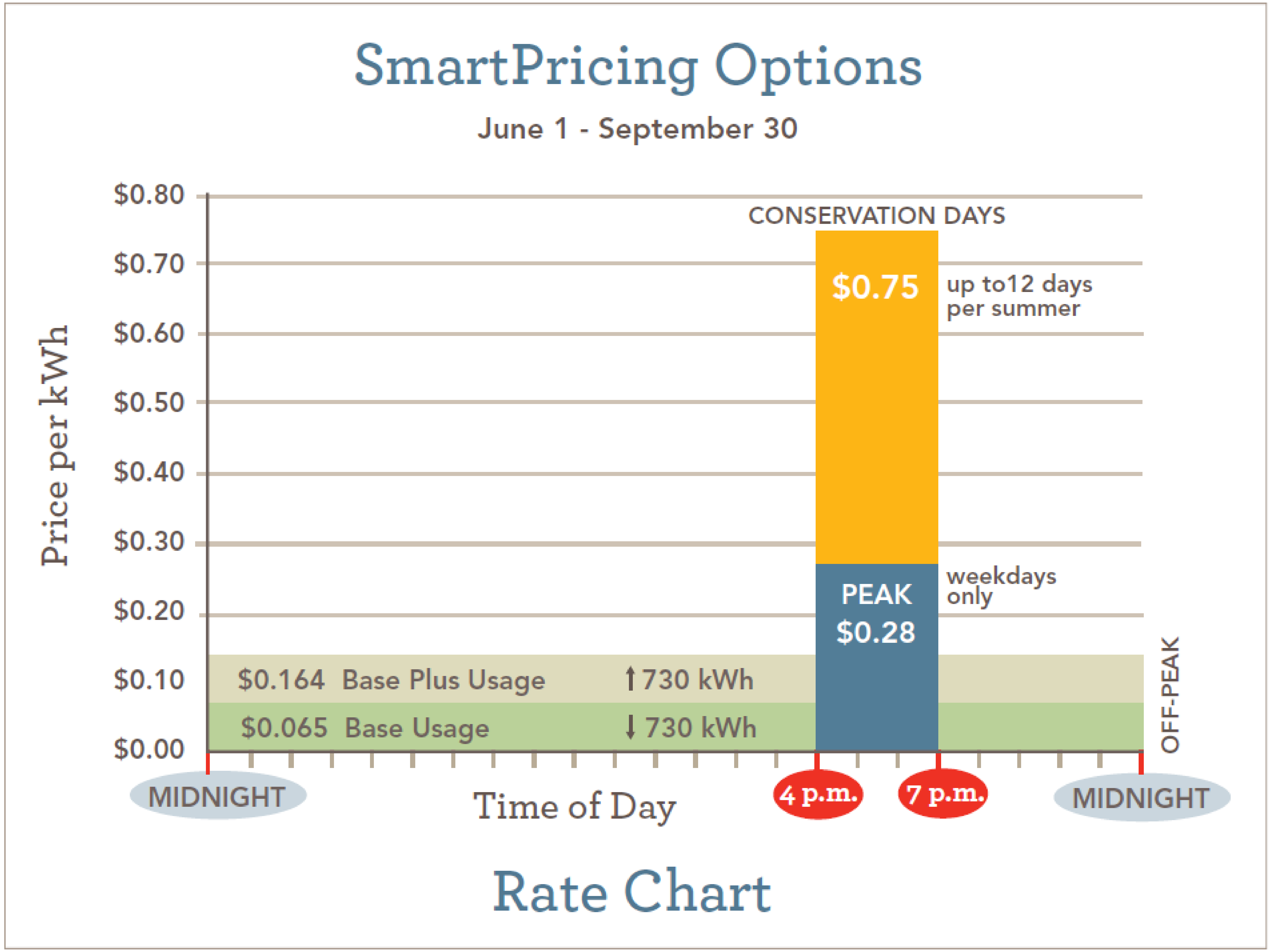
SIS dispatches to offset load in homes and export maximum additional energy to utility grid during DR events

Note: Height of graph shows total energy used in the home

SMUD TOU-CPP Rate Tariff

2015 Demonstration:

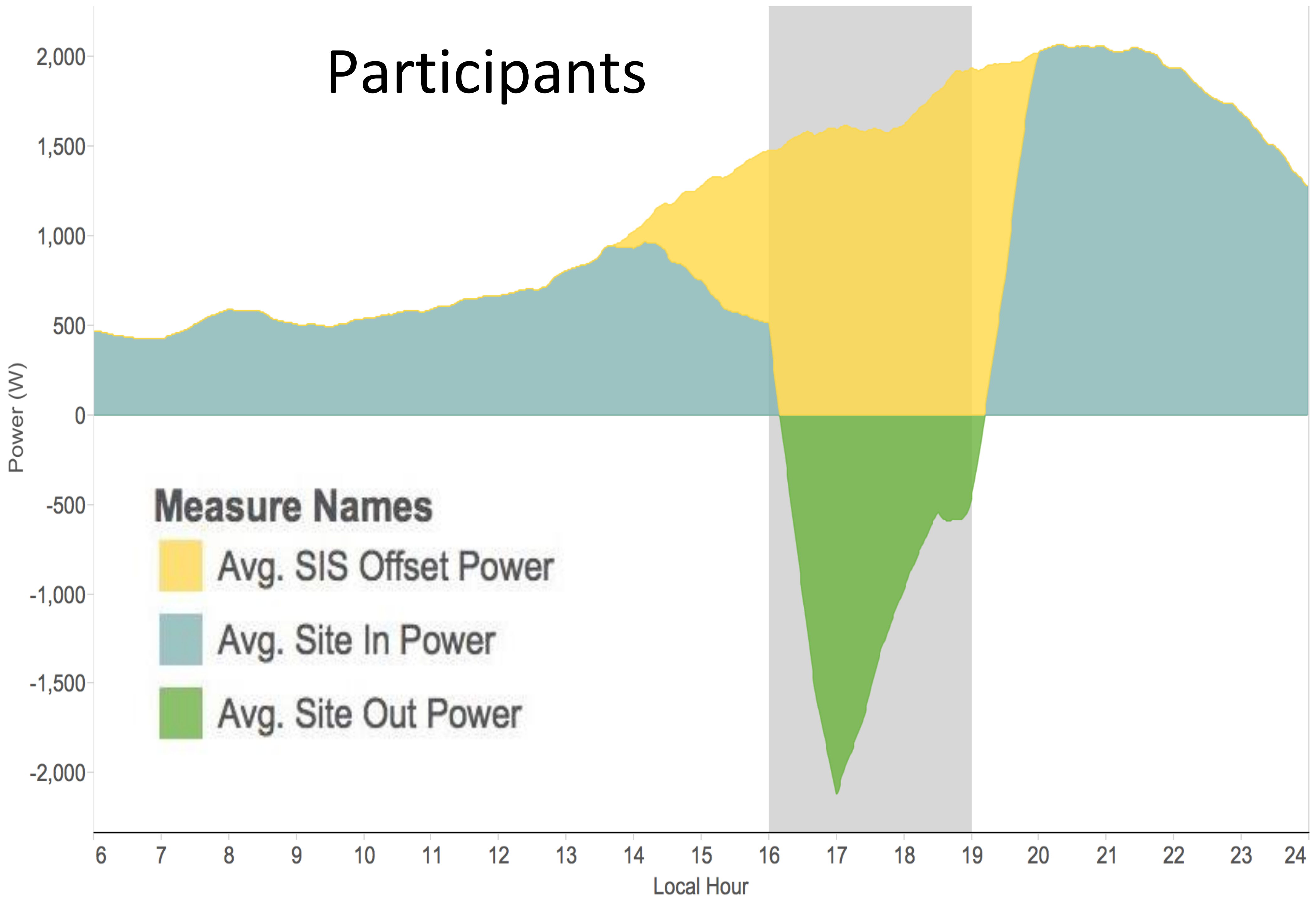
- 17 out of 34 homes enrolled in the SmartPricing Options tariff
- 9 total Conservation Days occurred
- Participants saw > 50% bill savings compared to non-participants
  - Savings from offsetting total load during peak period
  - Credit from energy arbitrage for higher-priced peak periods

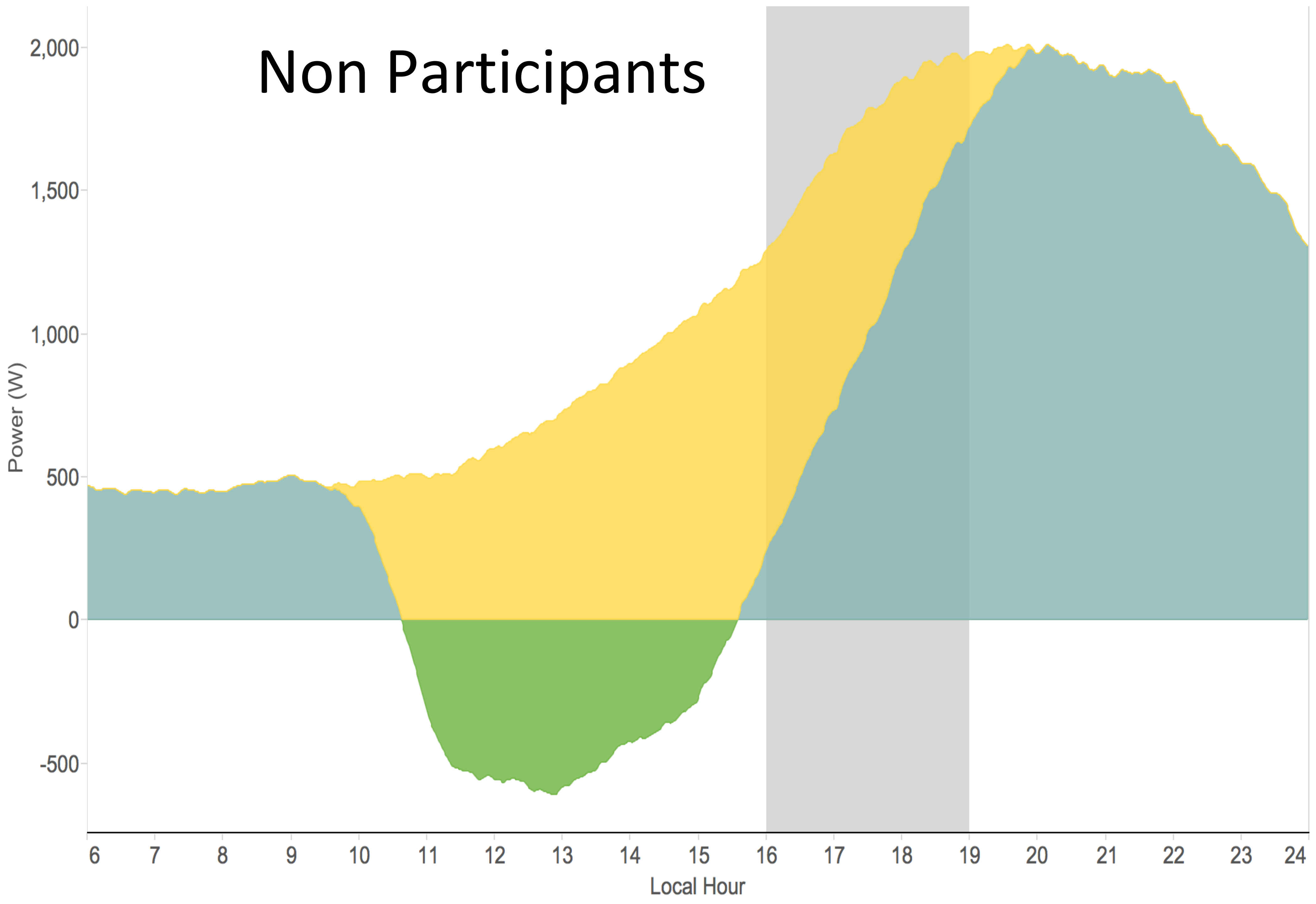


Performance on Conservation Days

The average for all conservation days June - September 2015 (9 days)

Note: One site was omitted from both graphs for comparison purposes

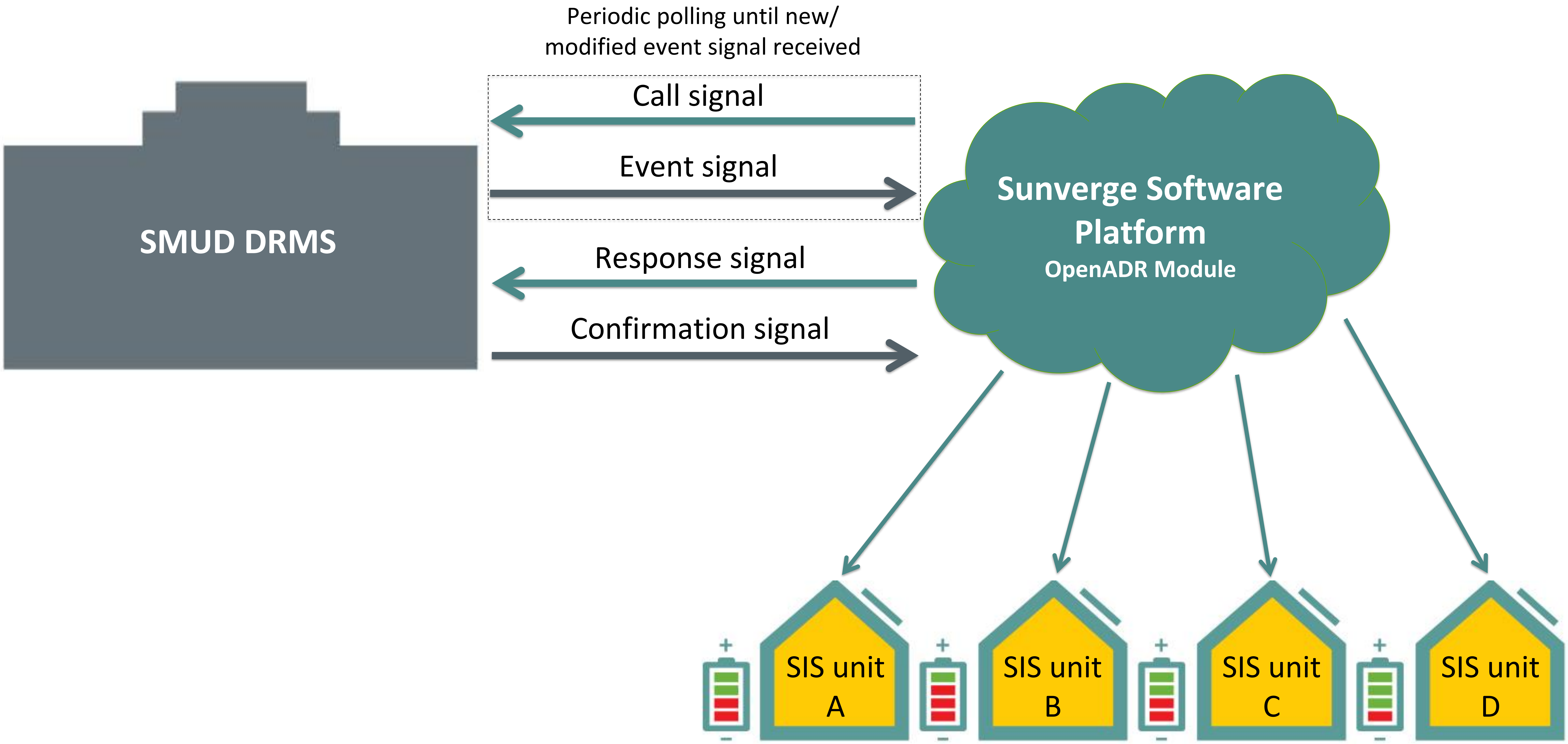




$$$$	HOMEOWNER BENEFIT	$
✓✓✓	UTILITY BENEFIT	X

Integrating
Demand Response Management System
with Sunverge Control Software

Manage Multiple DERs via OpenADR Integration



OpenADR Integration Process Map

1. Planning and Development

- Groups
- Signal Payload
- Event Tags
- Algorithms
- Connect to SMUD DRMS

2. OpenADR Signals

- Call signal
- Event signal
- Response signal
- Confirmation signal

3. Event Execution

- Event Schedule
- Capacity Forecast
- Enable Algorithms
- SIS Operation

OpenADR Integration Process Map

1. Program Planning and Development	2. Software Engineering Development with OpenADR Signals	3. Event Scheduling and Execution
2 MONTHS • Program planning	2 WEEKS • Engineering development	1 WEEK • Scheduling 2 MONTHS • Testing

DRMS Integration Testing (Oct – Nov 2015)

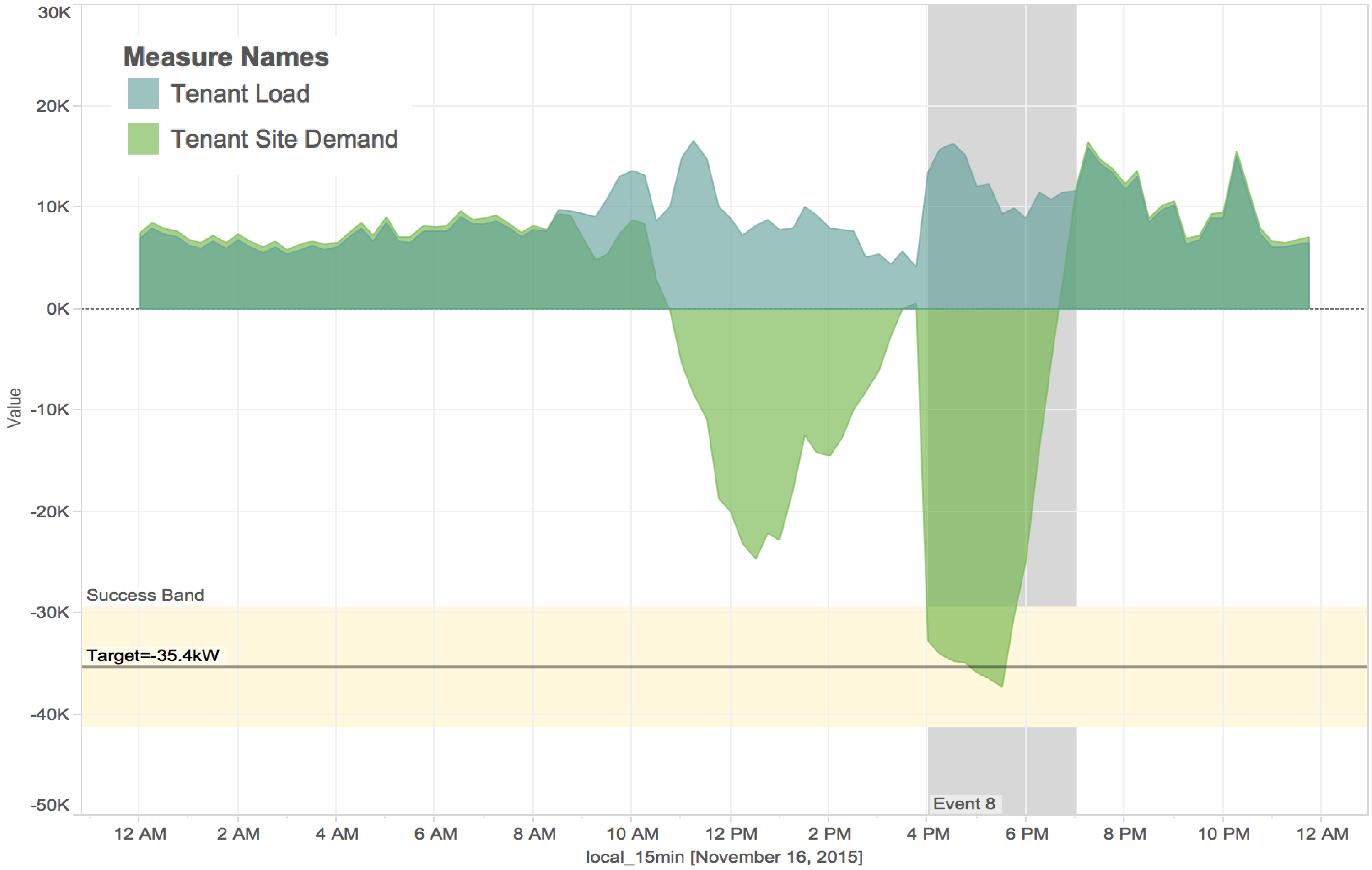
TEST DESCRIPTION

- Simulated 8 DR events of varying lengths and advanced notice
- 20 total participants volunteered
- Occurred after the TOU-CPP rate tariff

TEST GOALS & RESULTS

- Demonstrate DRMS and Sunverge software communications via OpenADR 2.0a protocol - **SUCCESS**
- Demonstrate advanced scheduled and emergency DR events - **SUCCESS**
- Load predictability – **CAN IMPROVE**
- Ability to forecast capacity fleet-wide – **CAN IMPROVE**
- Reduce grid impact while maintaining back-up power for customers - **SUCCESS**

EXAMPLE DEMAND RESPONSE TEST EVENT



OpenADR 2.0a Lessons Learned

PROS:

- Using OpenADR was an important first step in demonstrating how a utility can use DERs for demand response
- Establishing communication was straightforward and easy
- Protocol provided flexibility to define event parameters with additional data fields

CONS:

- Dynamic functionality to operate SIS fleet was lost in event signals that only allow basic details
- OpenADR 2.0a protocol lacked performance feedback loops to enable more dynamic controls
- OpenADR 2.0a protocol did not provide the ability to communicate grid capacity needs
- Advanced planning was necessary to define exact operations, which ill-suited for emergency DR events
- Still required development customization, so program could not be easily replicated with another utility

SUNVERGE

Key Takeaways

- 2500 R Midtown Project was a successful demonstration of aggregating distributed energy storage + solar of both utility and customer benefits
  – **Customers:** participants on the TOU-CPP rate tariff saved a lot on their bills by arbitraging energy for peak period compared to non-participants, while still being able to rely on available backup power
  – **Utility:** during peak periods and demand response events, loads to the distribution grid were completely offset and had net exports, which can be scaled up for greater impact
  – High PV exports during the day can be mitigated with predictable/reliable power dispatched during grid constrained periods (smoothing the “duck curve”)
- Demos allowed Sunverge to iterate its program algorithms to optimize for real-life use cases
- Integration between SMUD’s DRMS and Sunverge software using OpenADR was significant in proving the operation of VPP with a fleet of Sunverge SIS units
  – Future integrations with utility management systems should take into account utility use cases

SUNVERGE

SMUD Goals and Candidate Site Selection

Deepak Aswani

August 11, 2016

Powering forward. Together.

SMUD

SMUD's Goals for Distributed PV and Energy Storage

Need

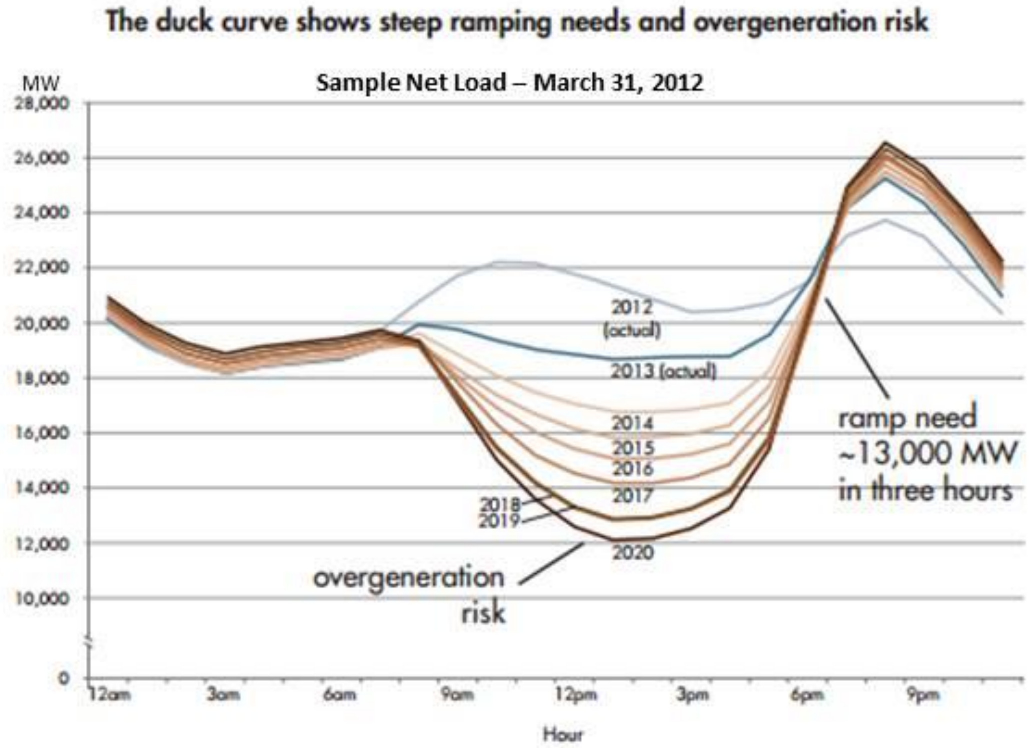
Utility operational challenges from increased solar market growth

Potential Adoption strategy

Share benefits between utility and residential customers for solar + storage

Research Question

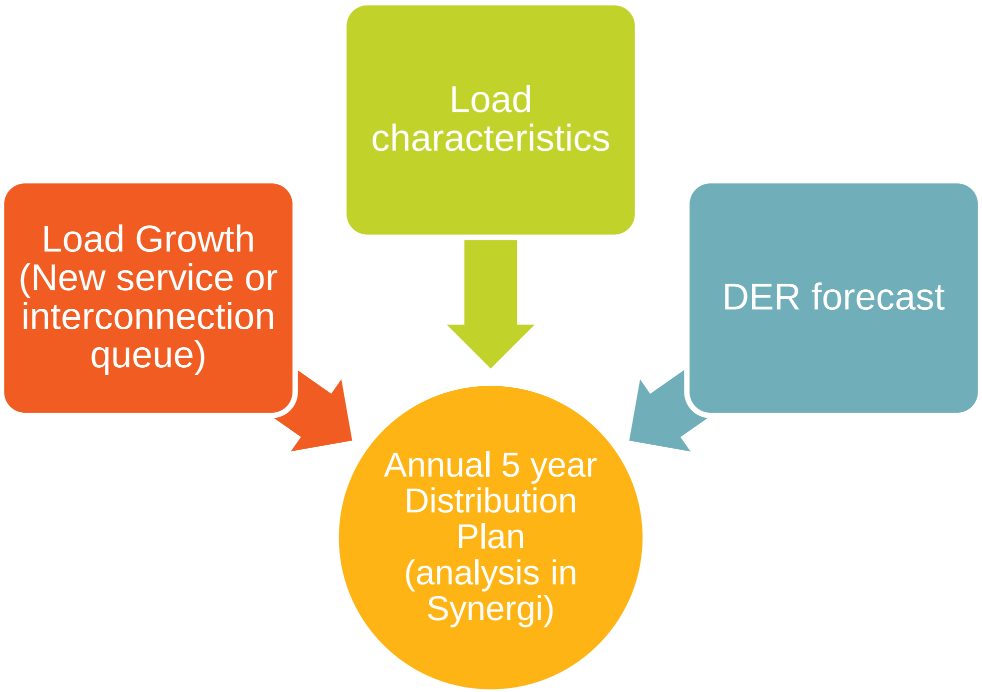
With storage not broadly cost effective, can locational needs build a business case for residential storage?



(from the California Independent System Operator)

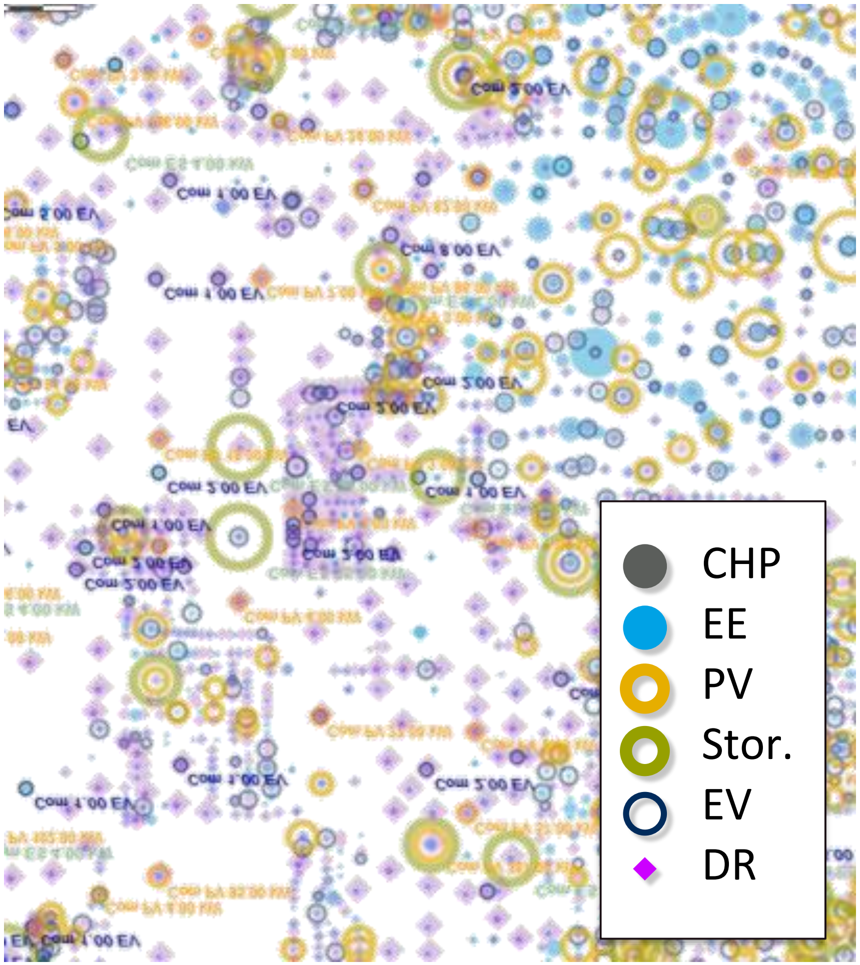
SMUD

Distribution Planning Process and Locational Potential



- Locational value potential in deferring capacity distribution infrastructure projects
- Only subset of projects may be candidates
  - How far past the capacity tipping point?
  - Nature of load growth – steepness and when?

New Addition - Locational DER Forecasts



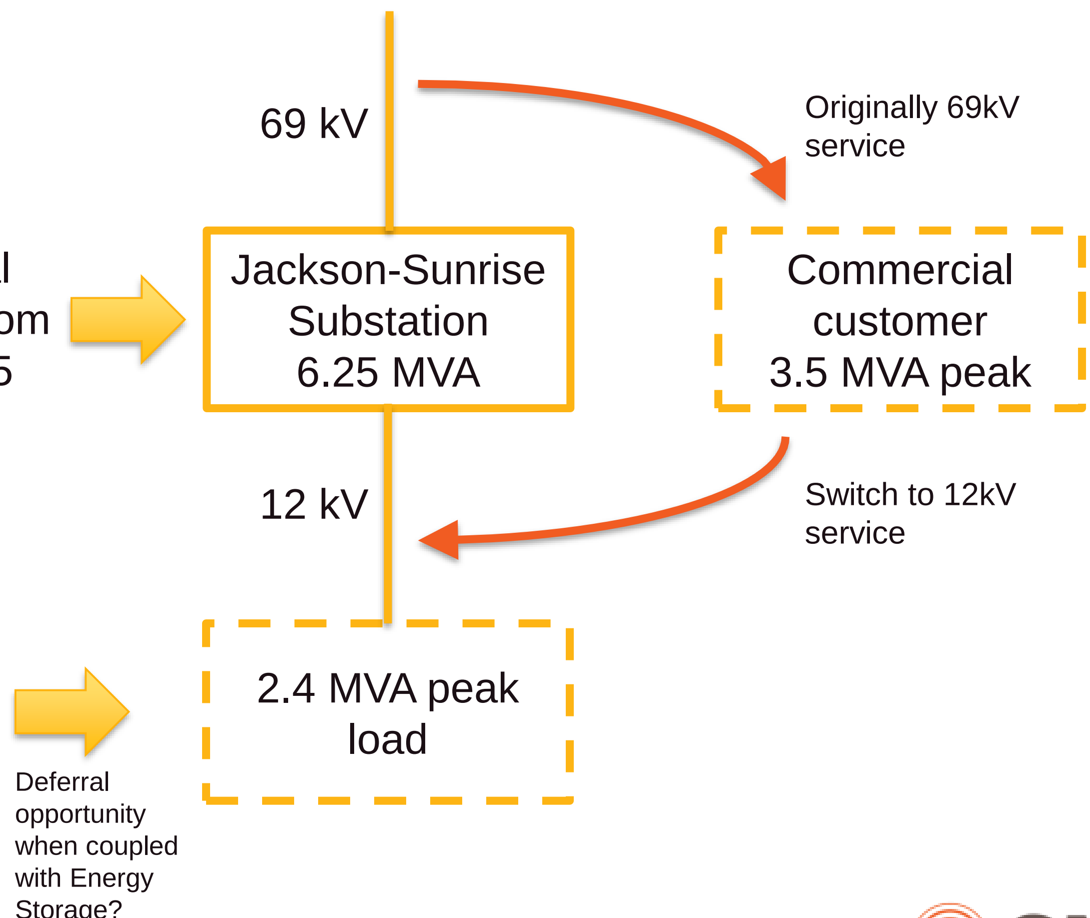
- Two modeled scenarios
  - Nominal PV adoption
  - High PV adoption
- Used prior dispersion analysis done by SMUD and Black & Veatch
- Considered
  - Technical potential of DER
  - Propensity based on adoption curves by customer segment

SMUD

Feeders Selected for Modeling

Jackson-Sunrise

Reduced ability to serve additional load growth. Local value in deferring upgrade from 6.25 MVA transformer to 12.5 MVA transformer

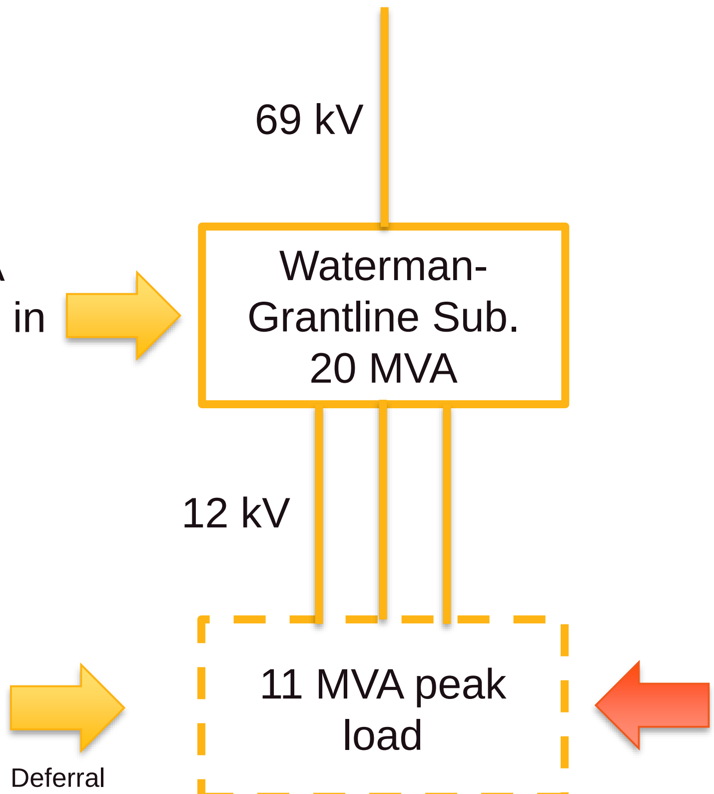


Year	High PV Scenario (installed BTM solar)
2015	0.16 MW
2020	0.32 MW
2030	0.44 MW

Feeders Selected for Modeling

Waterman-Grantline

Upgrade of additional 20 MVA bank anticipated. Local value in delay/deferral of upgrade.



Expected 22 MVA peak load growth by 2025

Year	High PV Scenario (installed BTM solar)
2015	0.17 MW
2020	0.81 MW
2030	1.06 MW

Deferral opportunity when coupled with Energy Storage?

Takeaways to Identify Distribution Deferral Candidates

- Margin of capacity constraints need to be small for a DER-based alternative to improve chances of being cost competitive

- Confidence in the timeframe and rate of load growth are important to realize avoided cost of capital

- Additional detail in planning assumptions can help more accurately identify technical and operational needs without being overly conservative

SMUD

Distribution System Impacts

Modeling SMUD's Waterman-Grantline Circuit

James Sherwood | August 11, 2016

ROCKY MOUNTAIN INSTITUTE

Modeling Distribution System Impacts

Objective

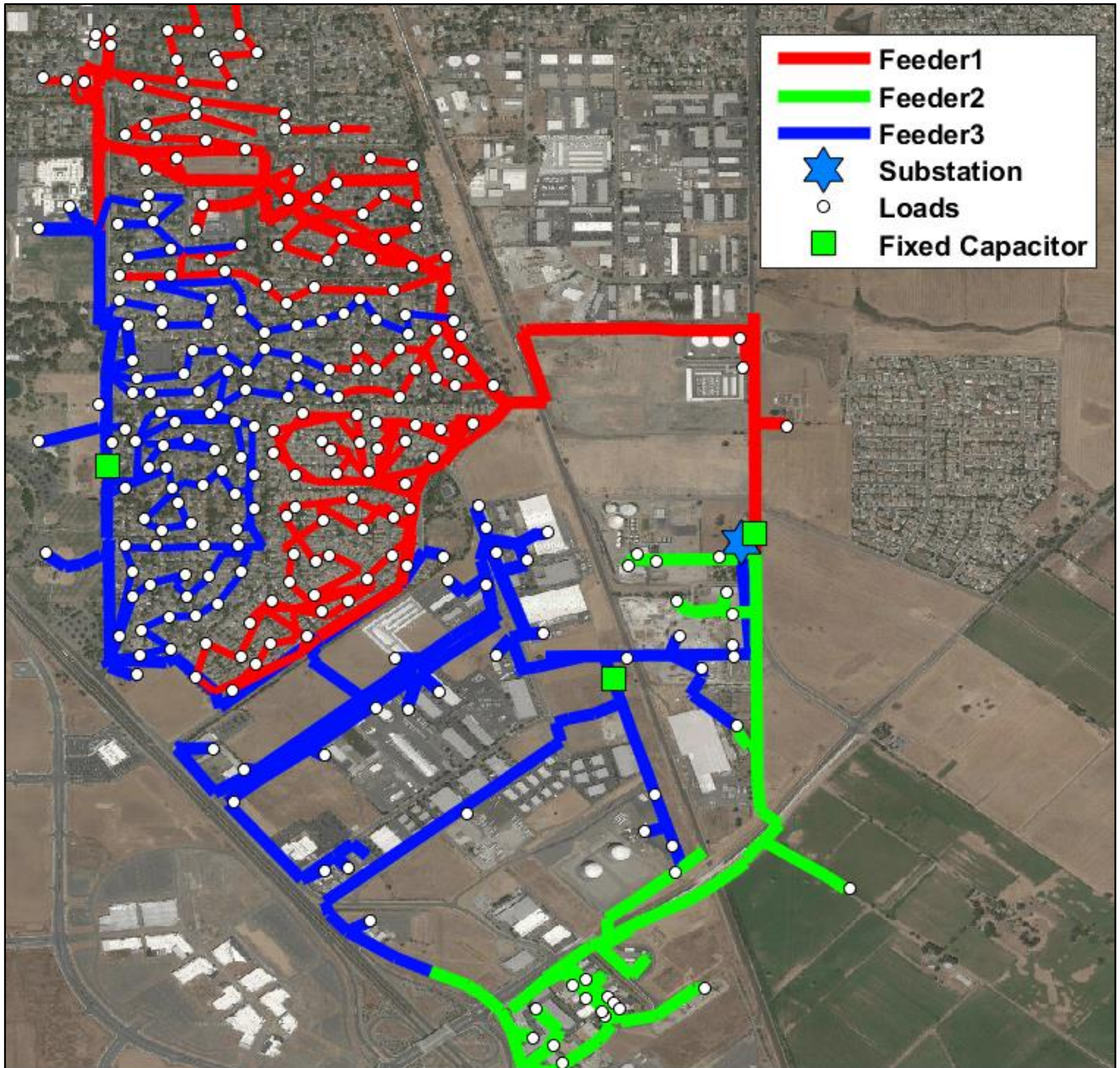
Develop robust estimates for local distribution system operational impacts, supported by power flow modeling

Key Considerations

- While distribution system operational impacts have been studied, few analyses have comprehensively assessed various potential value streams in one modeling exercise
- Quantifying local distribution system operational impacts—positive or negative—provides a better estimate to be used within the broader scope of this project

ROCKY MOUNTAIN INSTITUTE

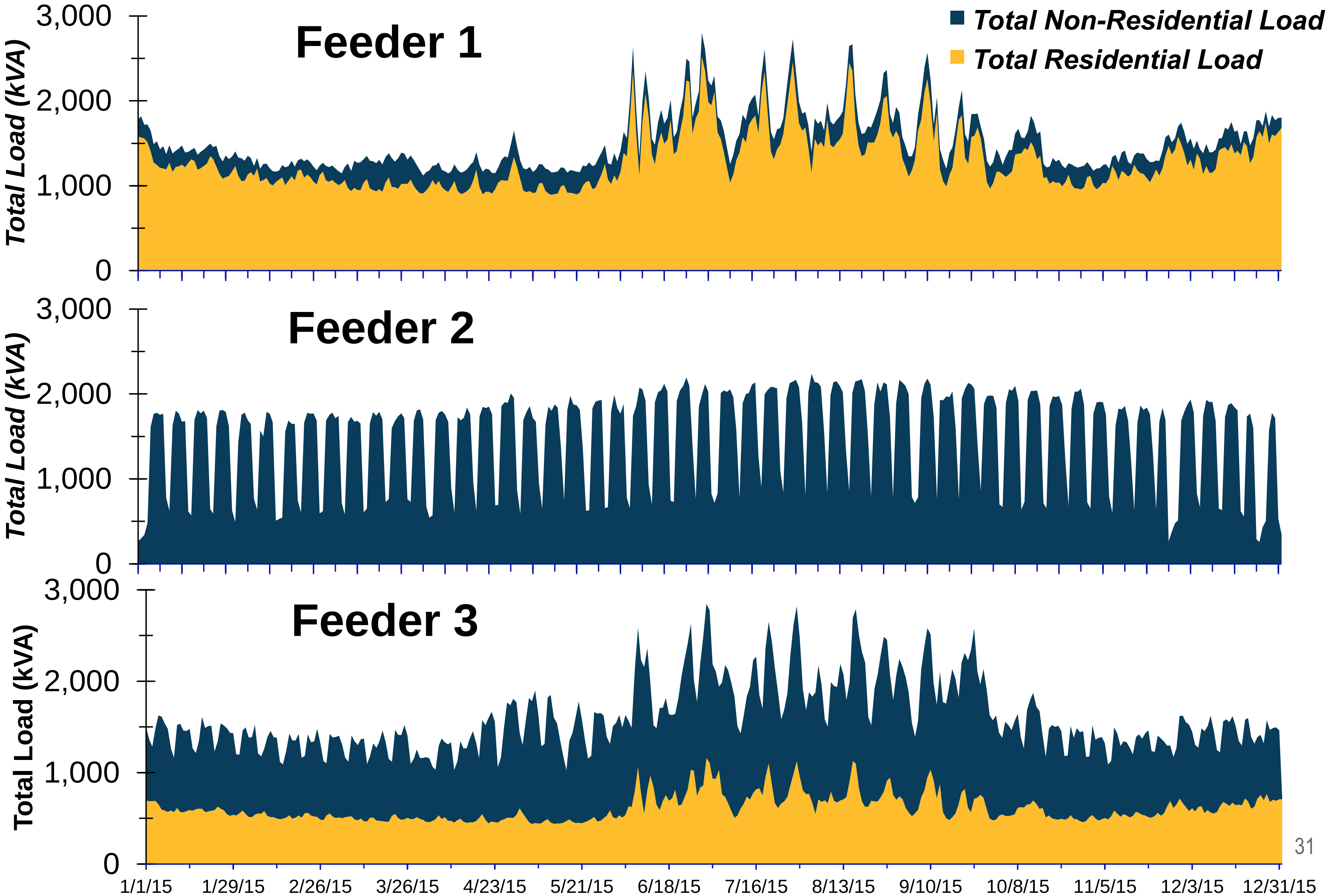
Waterman-Grantline Circuit Characteristics



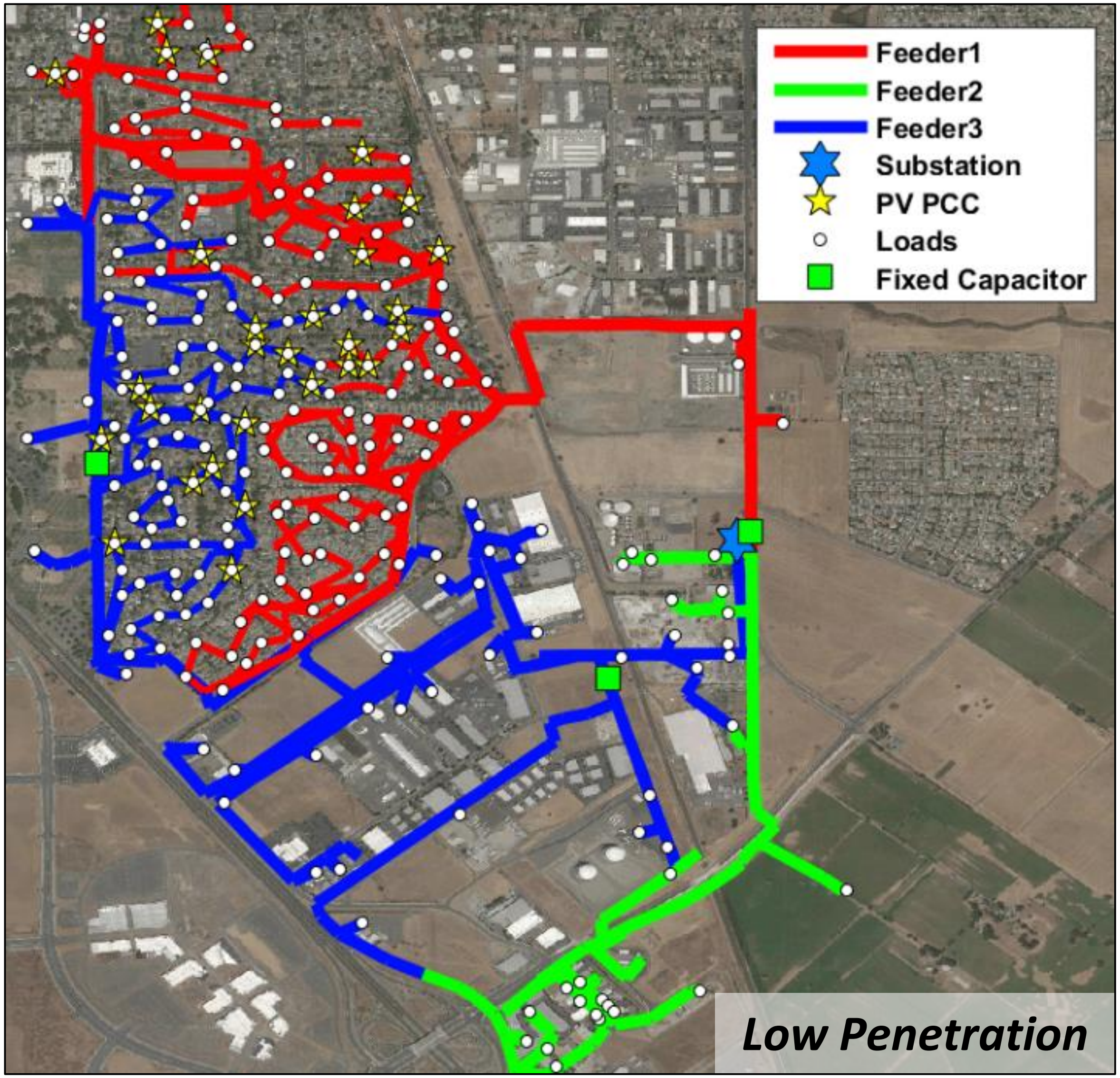
Key Characteristics

- Total of 2,018 customers
  - 86% residential
- Three unique feeders:
  - Mostly residential (#1)
  - Mostly commercial (#2)
  - Mixture of both (#3)

Waterman-Grantline Feeder Loading



PV SIS System Deployment

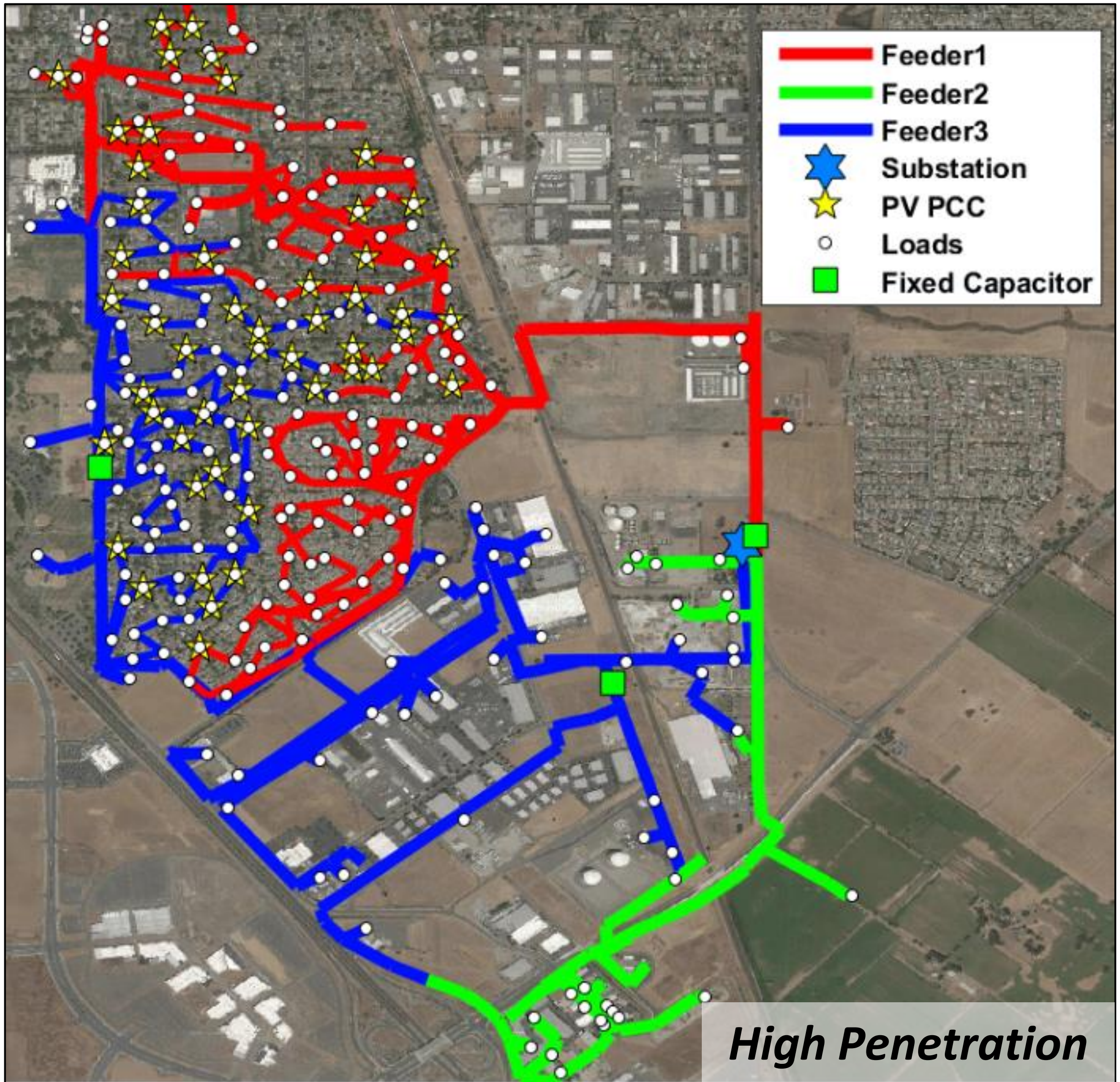


Deployment Summary

Analysis considered:

- Three technology scenarios:
  1. PV Only
  2. SIS, Utility Dispatch
  3. SIS, Customer Dispatch
- For each technology scenario, included two penetration scenarios:
  1. Low penetration
  2. High penetration
- Systems deployed using random distribution across residential customers

PV SIS System Deployment



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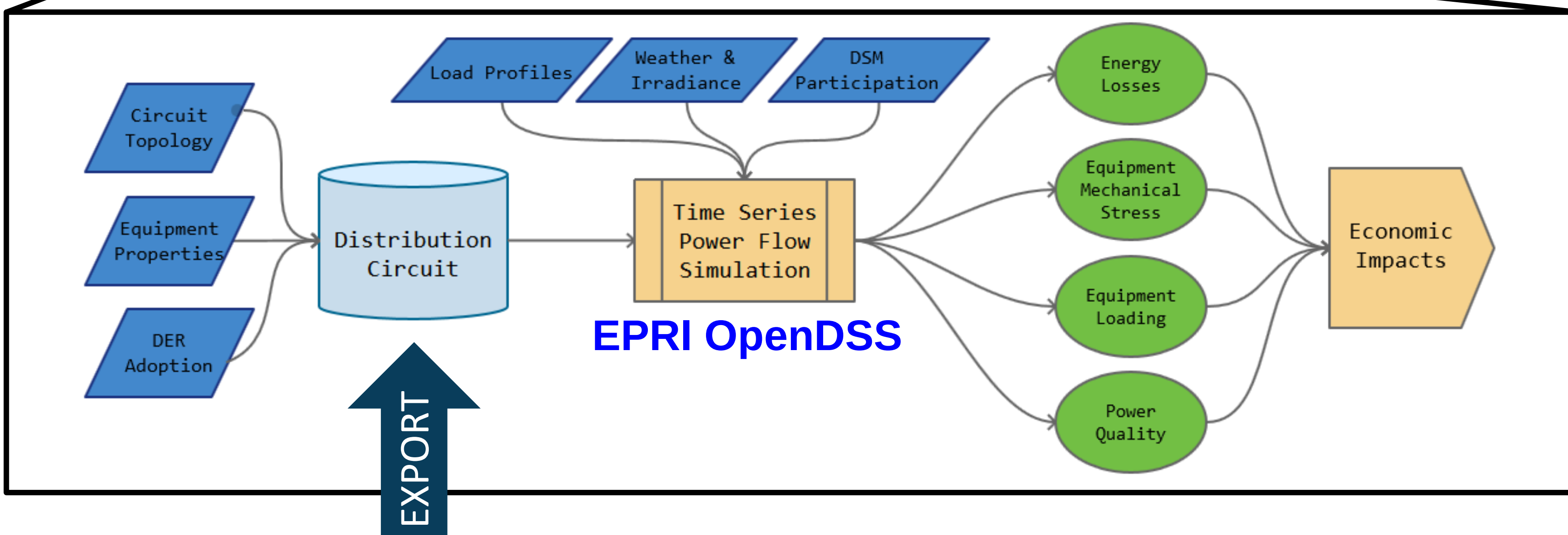
Sources of Value Considered in Analysis

	Metric	Motivation
1 Energy Losses	Cumulative annual energy losses across the distribution circuit.	PV and SIS may reduce the net load on the circuit, and therefore the losses.
2 Equipment Mechanical Stress	Total number of annual switching operations for individual assets.	PV and SIS may affect the operation of equipment, either reducing or increasing wear-and-tear.
3 Equipment Loading	Quantity, magnitude, and duration of overload events; hours of equipment use.	PV and SIS may affect the net load on equipment, and the hours of equipment use.
4 Power Quality	Quantity, magnitude, and duration of under- and over-voltage events.	PV and SIS could obviate or defer the need for new equipment to maintain power quality.

Modeling Tools and Approach

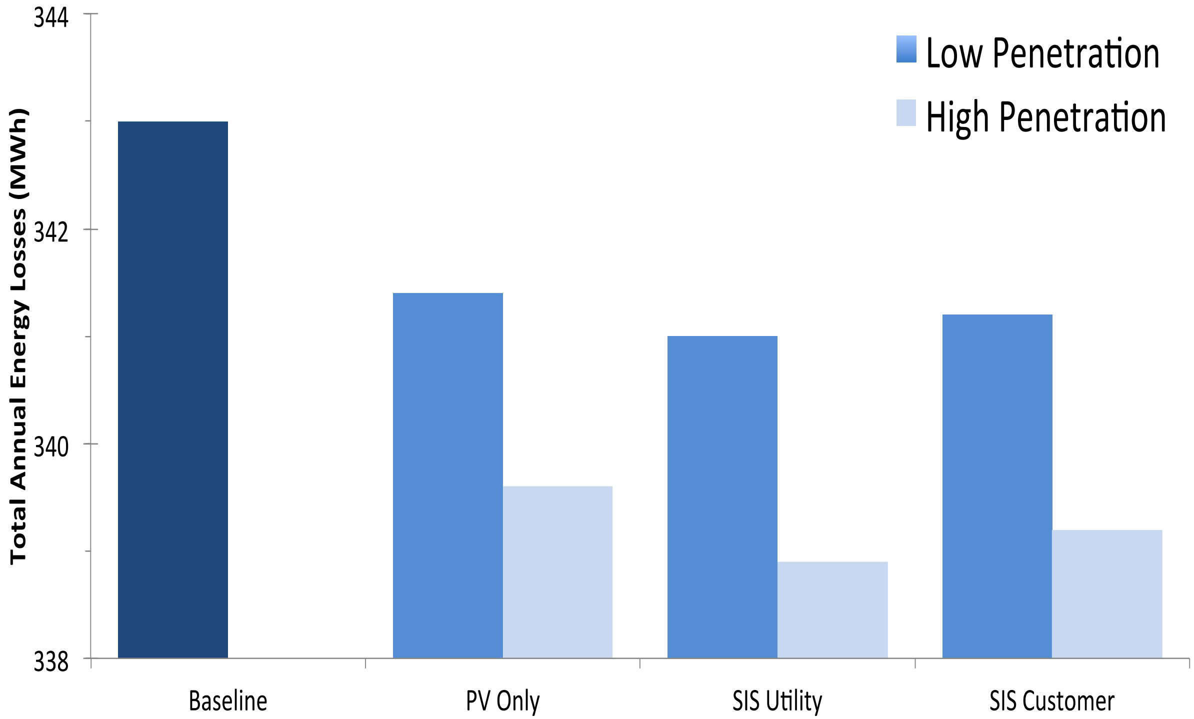
RMI Electricity Distribution Grid Evaluator (EDGE) model



DNV-GL Synergi Electric model used in SMUD 5 yr planning

SMUD

Results: Energy Losses

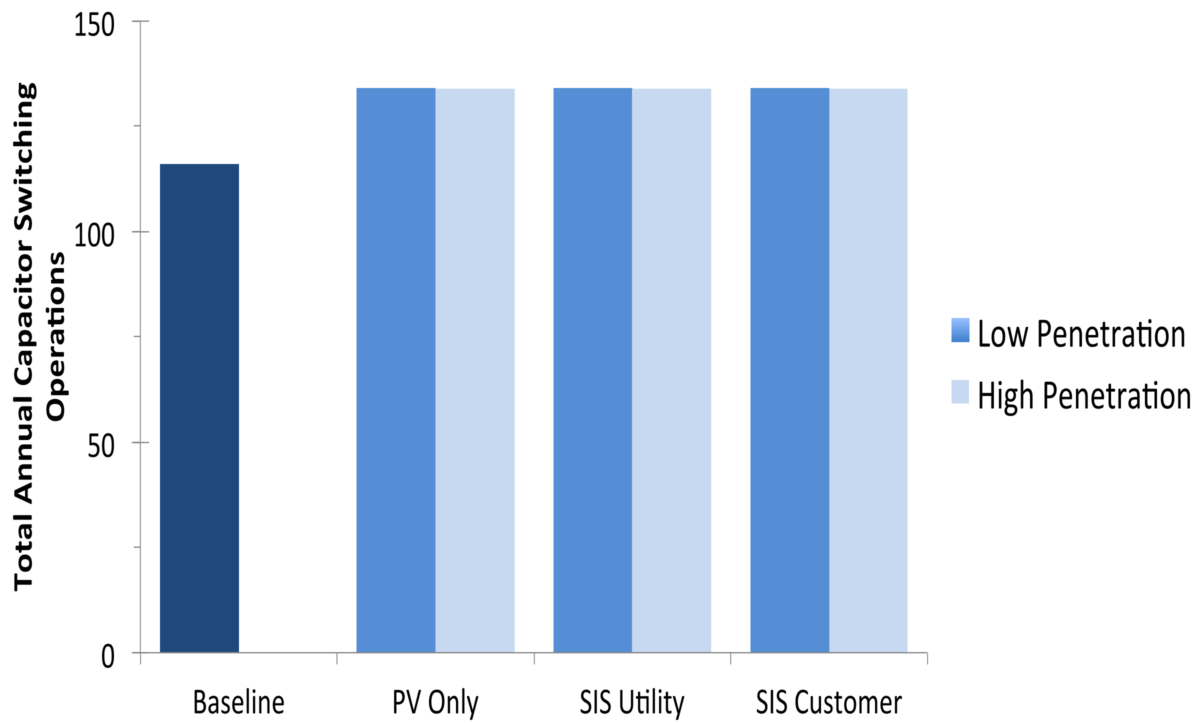


Key Takeaways

- Adding PV and SIS results in lower energy losses on the circuit.
- Adding PV alone to the system decreased losses by 1.6–3.4 MWh/year
- Adding storage decreased losses by 12–22% over PV alone.
- The storage dispatch algorithm impacts the change in losses.

		Low Penetration			High Penetration		
	Baseline	PV Only	SIS (Utility Dispatch)	SIS (Customer Dispatch)	PV Only	SIS (Utility Dispatch)	SIS (Customer Dispatch)
Change in Total Annual Energy Losses (MWh)	-	-1.6	-2.0	-1.8	-3.4	-4.1	-3.8
Change Relative to 'PV Only' Scenario	-	-	-21.5%	-12.3%	-	-20.9%	-12.7%

Results: Equipment Mechanical Stress—Capacitors

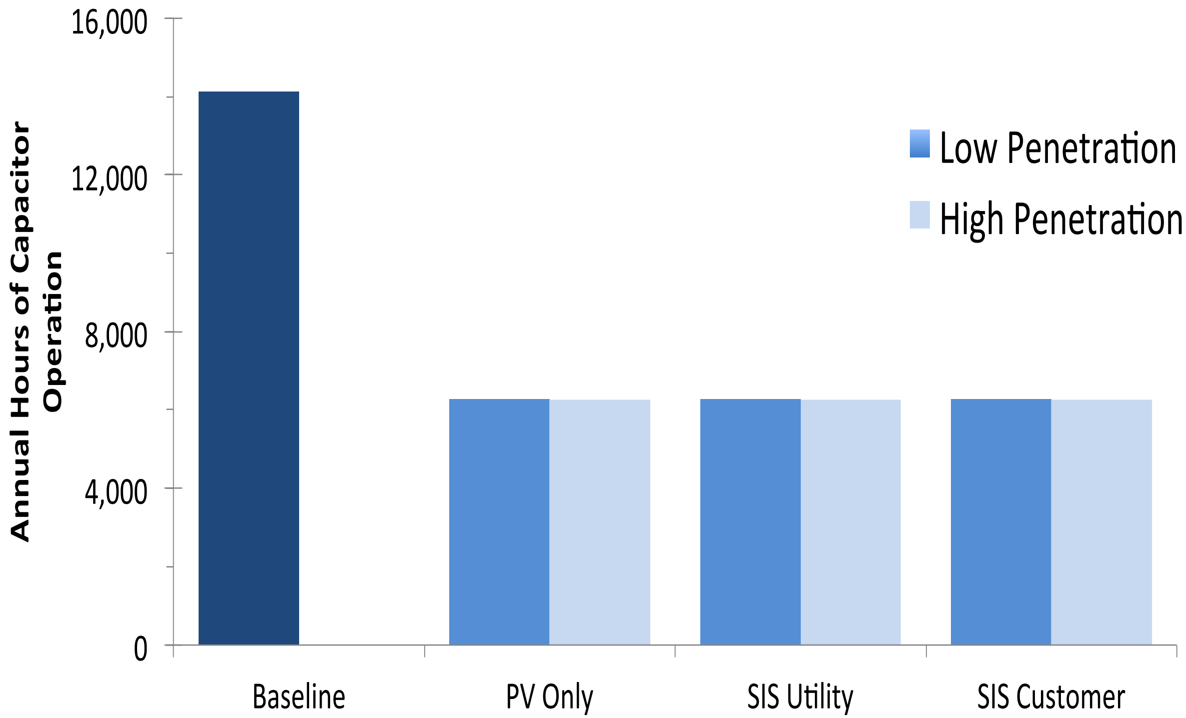


Key Takeaways

- Across the 3 capacitors, total annual switching operations increased slightly with PV and SIS.
- Capacitor #3 is switched slightly more frequently with PV and SIS.
- However, Capacitor #2 is no longer used—it could be removed and utilized on another circuit as needed.

		Low Penetration			High Penetration		
	Baseline	**PV Only**	**SIS (Utility Dispatch)**	**SIS (Customer Dispatch)**	**PV Only**	**SIS (Utility Dispatch)**	**SIS (Customer Dispatch)**
Annual Switching Operations for Cap #1	112	112	112	112	112	112	112
Annual Switching Operations for Cap #2	2	0	0	0	0	0	0
Annual Switching Operations for Cap #3	2	22	22	22	22	22	22

Results: Equipment Loading—Capacitors

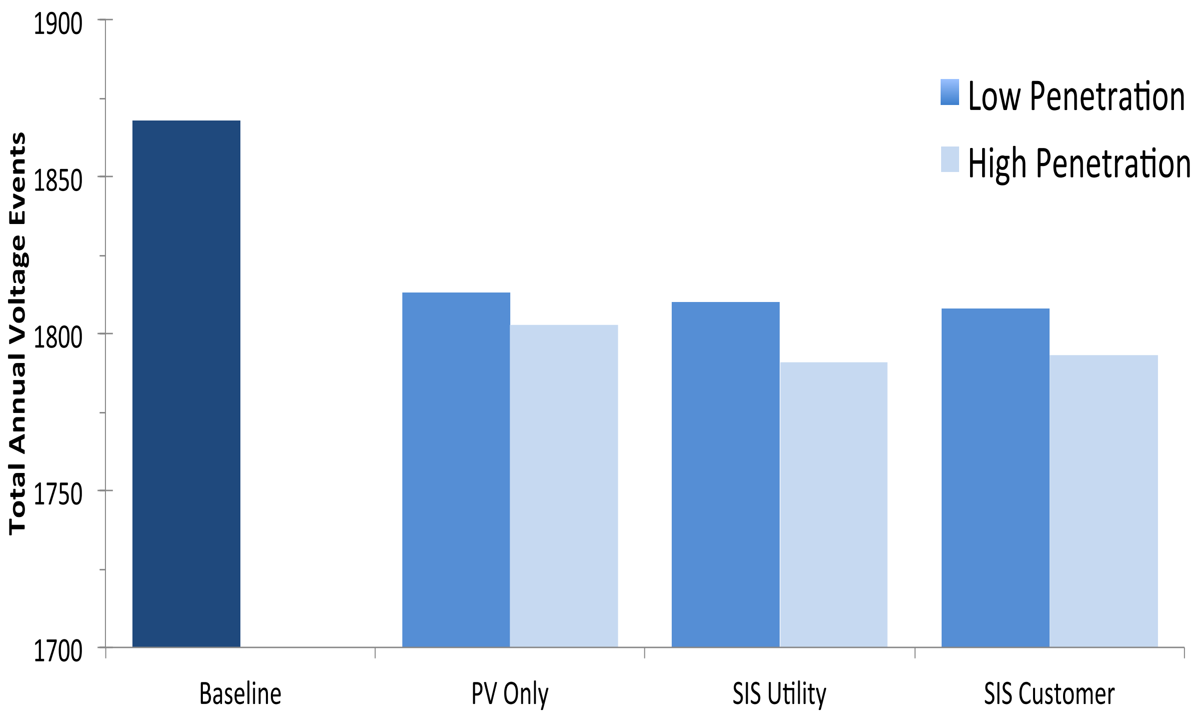


Key Takeaways

- Total annual hours of operation decreases significantly with PV alone; adding storage does not cause additional reduction.
- The hours of operation for Capacitor #3 are most significantly reduced.

		Low Penetration			High Penetration		
	Baseline	PV Only	SIS (Utility Dispatch)	SIS (Customer Dispatch)	PV Only	SIS (Utility Dispatch)	SIS (Customer Dispatch)
Annual Hours of Operation for Cap #1	6,239	6,238	6,238	6,238	6,238	6,238	6,238
Annual Hours of Operation for Cap #2	16	0	0	0	0	0	0
Annual Hours of Operation for Cap #3	7,872	41	41	41	41	41	41

Results: Power Quality



Key Takeaways

- The total number of annual voltage events decreased when PV and SIS were added.
- Most of these voltage events are minor—alternative storage dispatch algorithms could be used to address many of them.

		Low Penetration			High Penetration		
	Baseline	**PV Only**	**SIS (Utility Dispatch)**	**SIS (Customer Dispatch)**	**PV Only**	**SIS (Utility Dispatch)**	**SIS (Customer Dispatch)**
Total Annual Under-Voltage Events	1,338	1,281	1,278	1,276	1,271	1,245	1,250
Total Annual Over-Voltage Events	530	532	532	532	532	546	543

Summary and Future Work

Key Takeaways

- Modest operational benefits with distributed PV and storage were seen in the model results (energy losses, equipment loading, power quality)
- Adding storage results in a slight increase in operational benefits relative to adding PV alone
- Results affirm findings from prior studies—operational benefits from DERs are highly location specific
- This analysis considered a single circuit, which is not necessarily representative of SMUD's entire distribution system

Suggested Next Steps

- Further evaluate potential savings from equipment operations
  - i.e., analyze circuits that contain switched components, such as LTCs and voltage regulators, which may see a change in their operation with distributed resources
- Evaluate the impact of new storage algorithms targeted at improving distribution system operations

Thank You

Questions?

www.rmi.org

Contact: James Sherwood | jsherwood@rmi.org | 303.567.8599

Energy+Environmental Economics

Distribution Grid Impacts and Ratepayer Benefits

Eric Cutter
Director, Distributed Energy Resources

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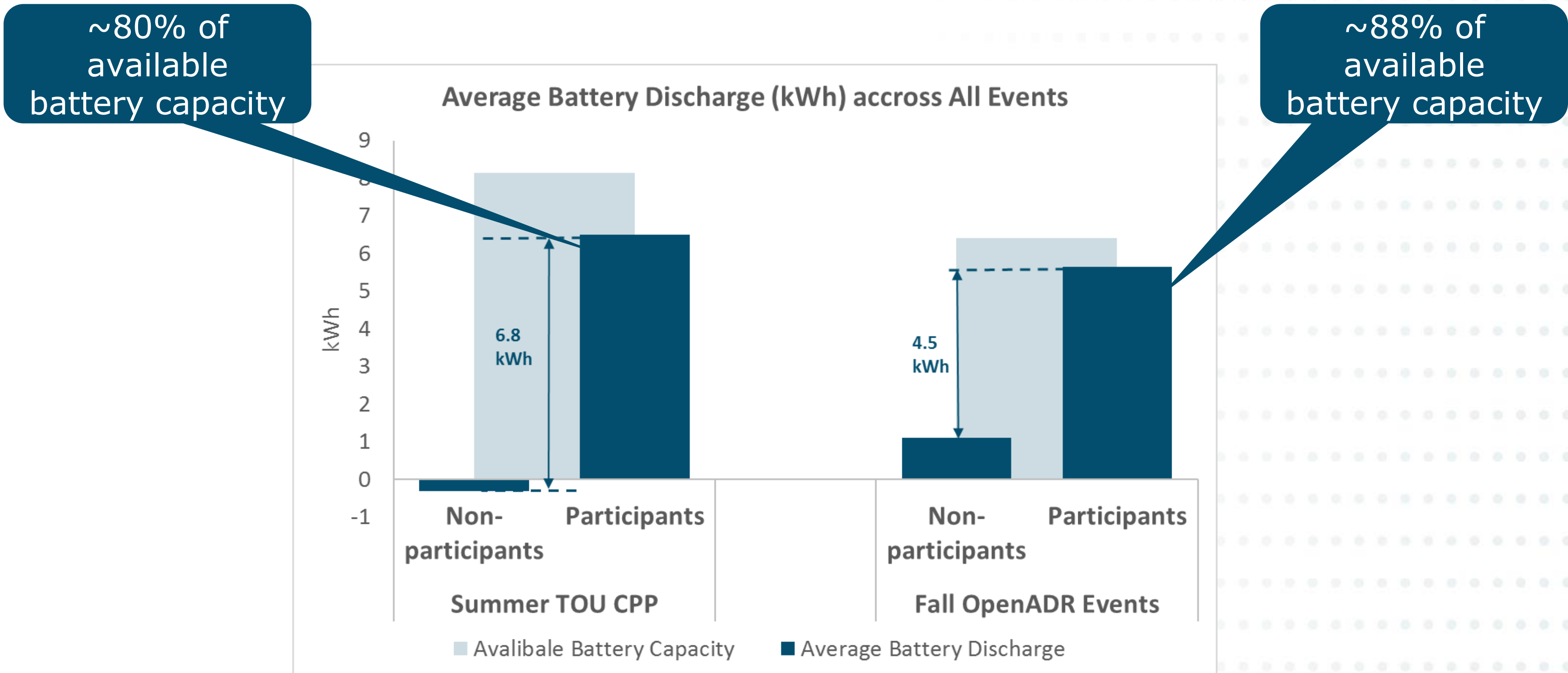
August 11, 2016

Tested events

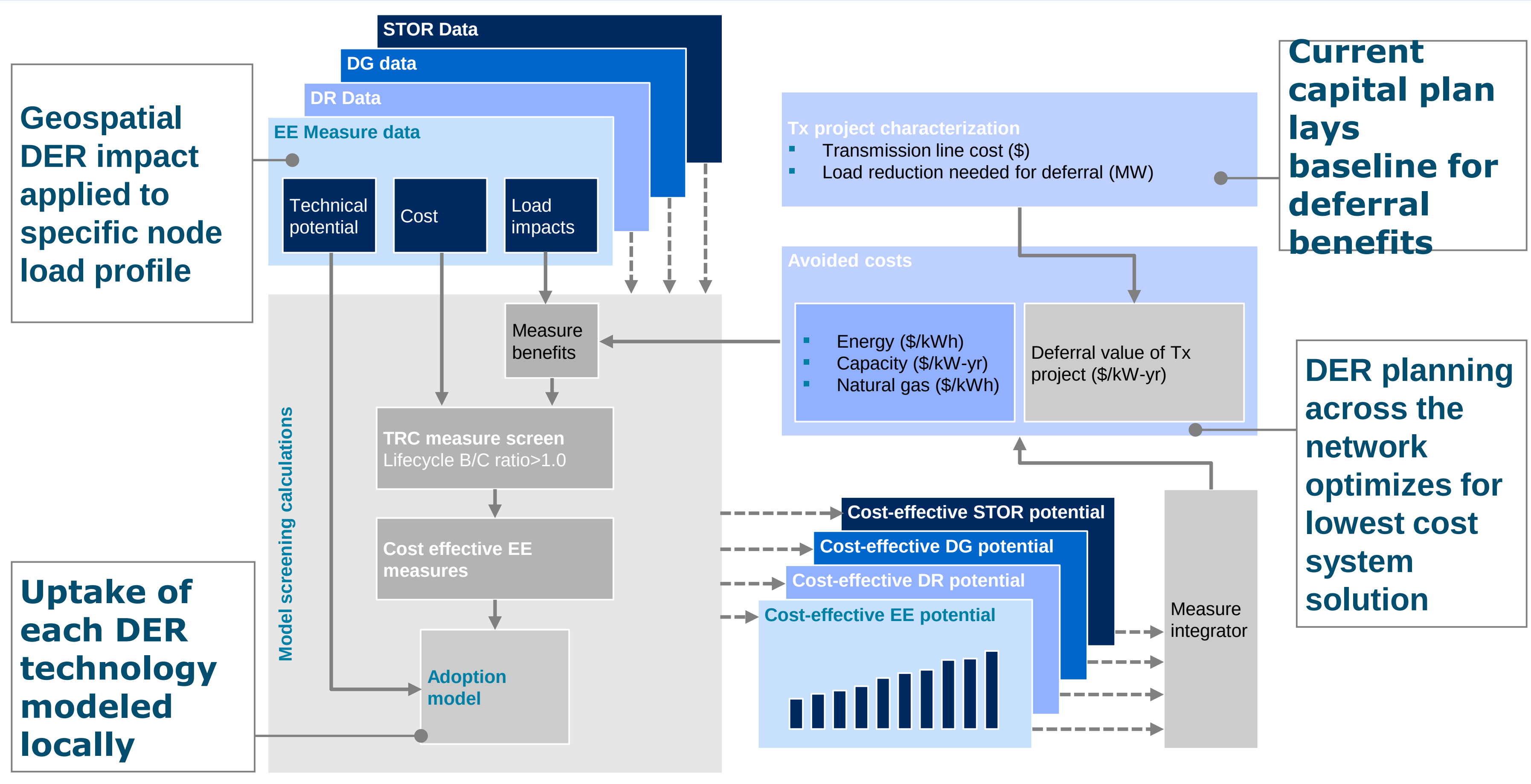


Summer TOU-CPP	Fall OpenADR
9 CPP Events called day-ahead for 4-7 PM	8 events of varying duration both day-ahead and day-of notification

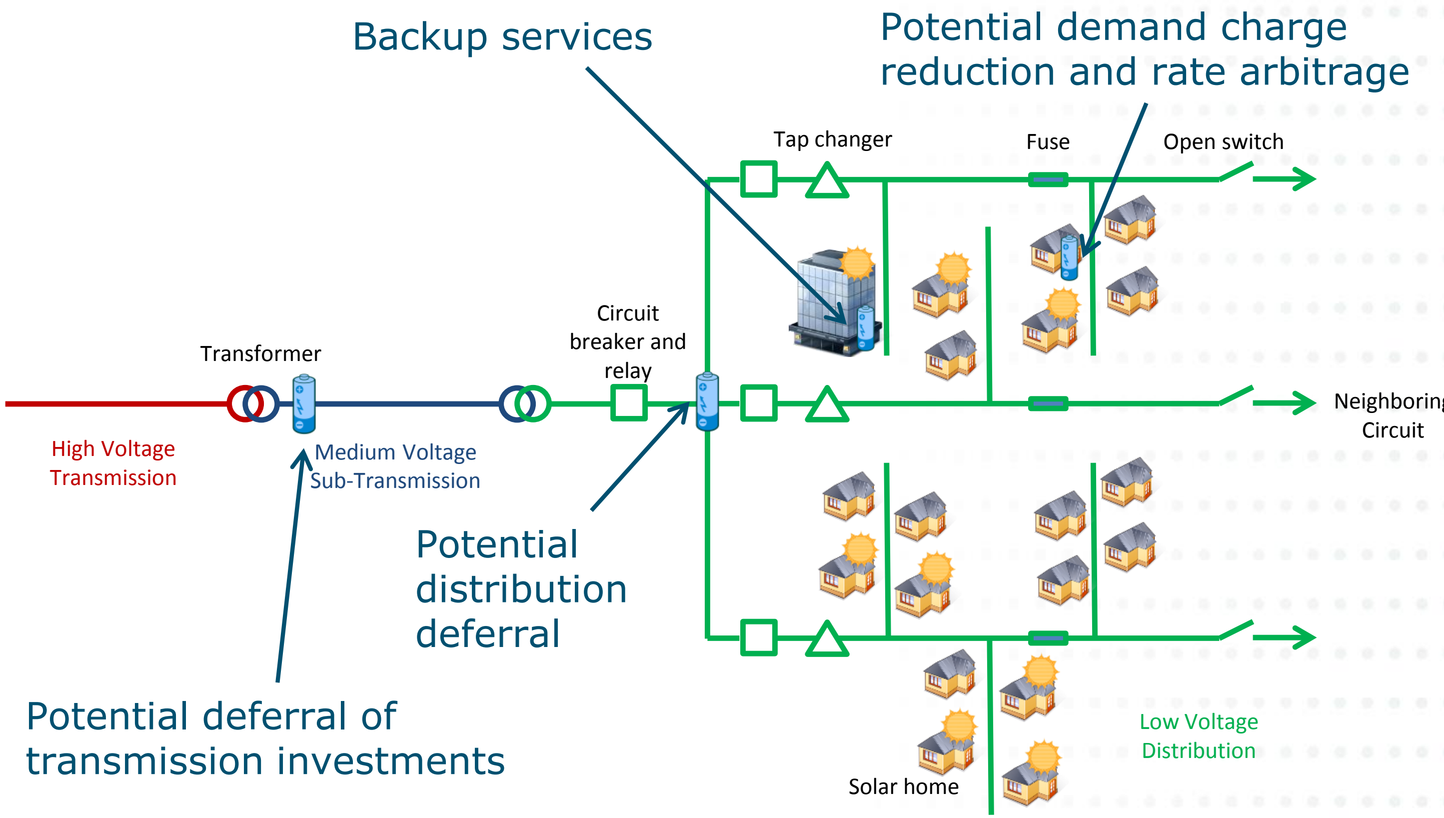
IDER Modeling Approach

Integrated Distributed Energy Resource Planning

Schematic of optimization tool



Local and Customer Benefits of Storage

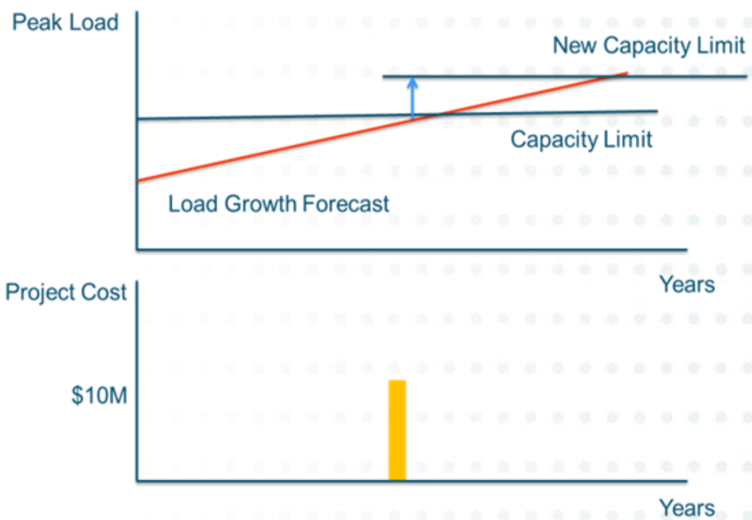


Benefits:

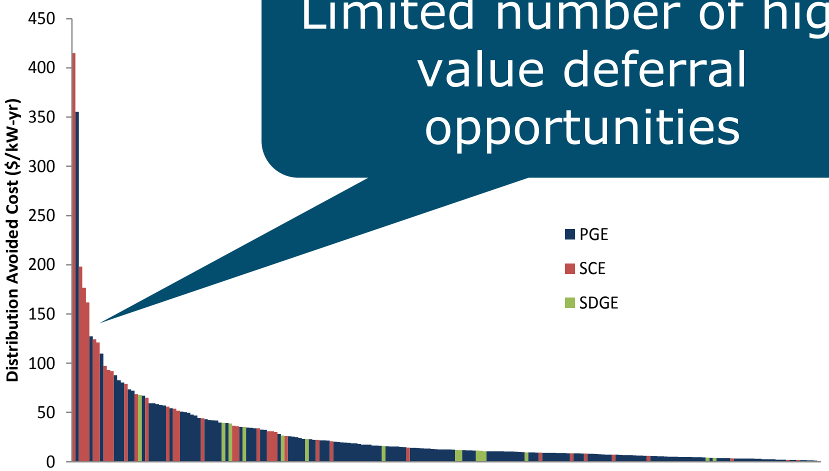
- System value streams
- Deferred investments in the distribution and transmission system related to load growth
- Demand charge reduction, back up, rate arbitrage
- Reliability and power quality

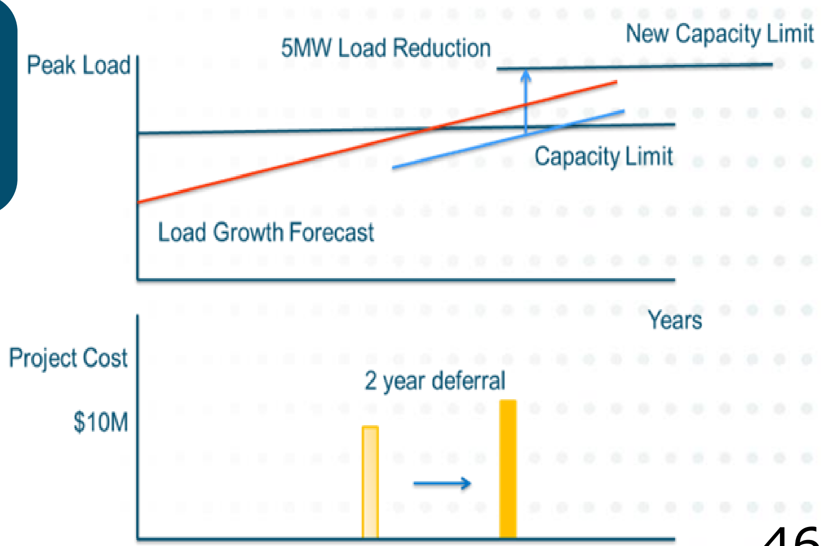
Distribution Deferral Value

- **Storage can defer load driven distribution investments**
- **Present Worth method used to calculate deferral value**
  - Used for CPUC Avoided Costs and CEC Title 24 Building Standards



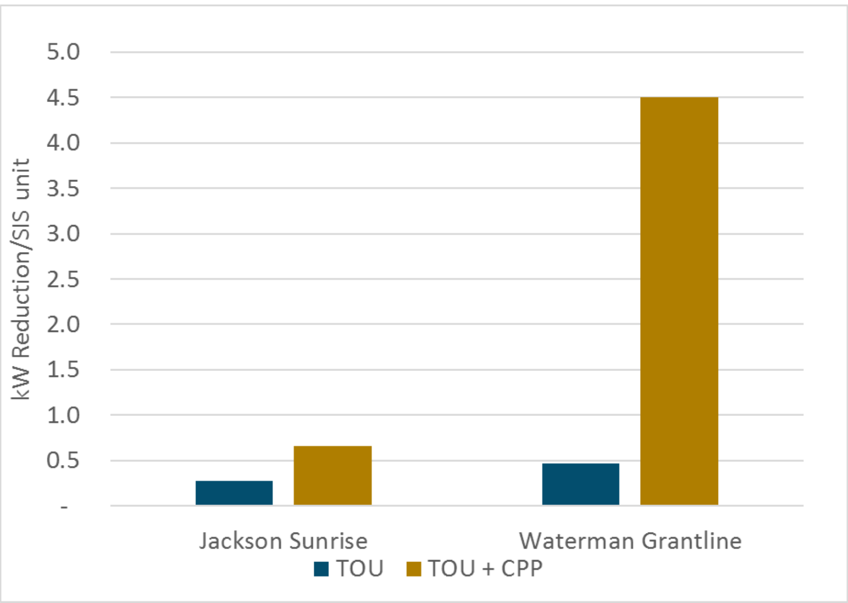
Limited number of high value deferral opportunities





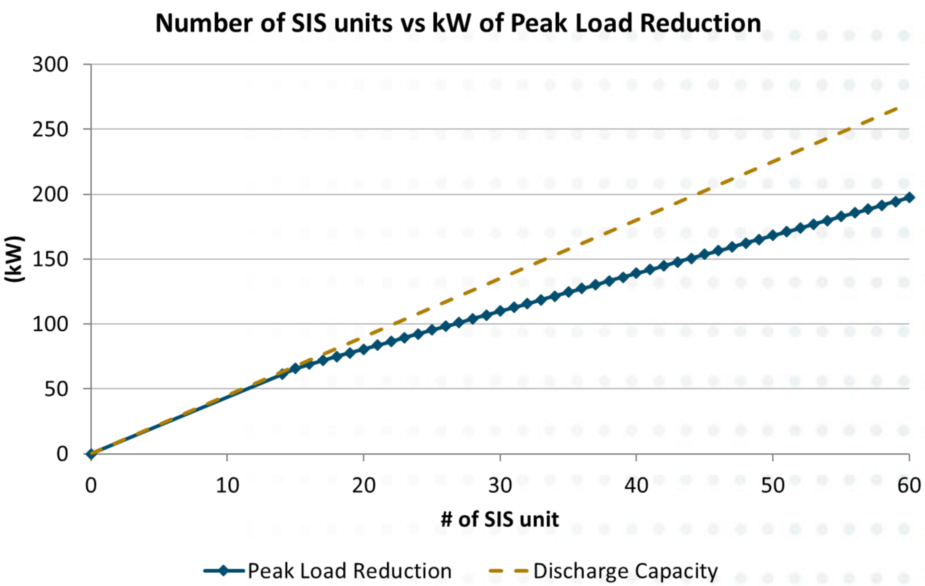
Peak Load Reduction

Jackson-Sunrise vs. Waterman-Grantline



CPP period of 4-7pm aligns well with distribution peak for Waterman-Grantline, but not Jackson Sunrise

Jackson-Sunrise Peak kW reduced per kW of storage installed



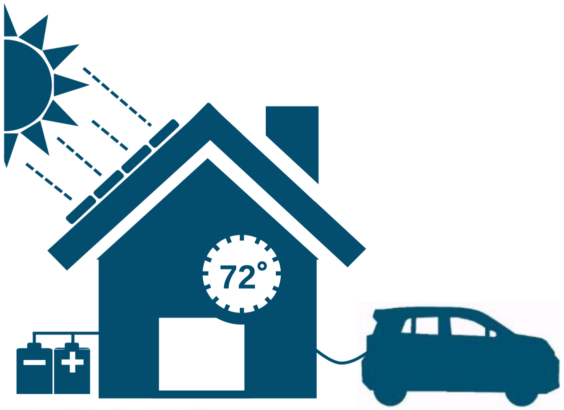
Declining marginal impact of storage with increasing penetration after certain point

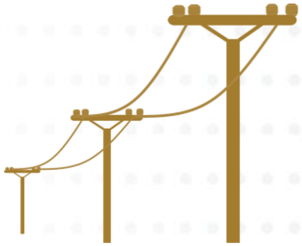
Two Operating Mode for Battery

+ **Model allows battery to operate in the following two modes to maximizing savings from either utilities or customers' perspective**

+ **Customers Perspective:**
  - Energy & Demand charge savings
  - Ancillary Service Revenue
  - Back-up power

+ **Utilities Perspective:**
  - Distribution Deferral Value
  - Total System Avoided Costs
  - Ancillary Service Revenue

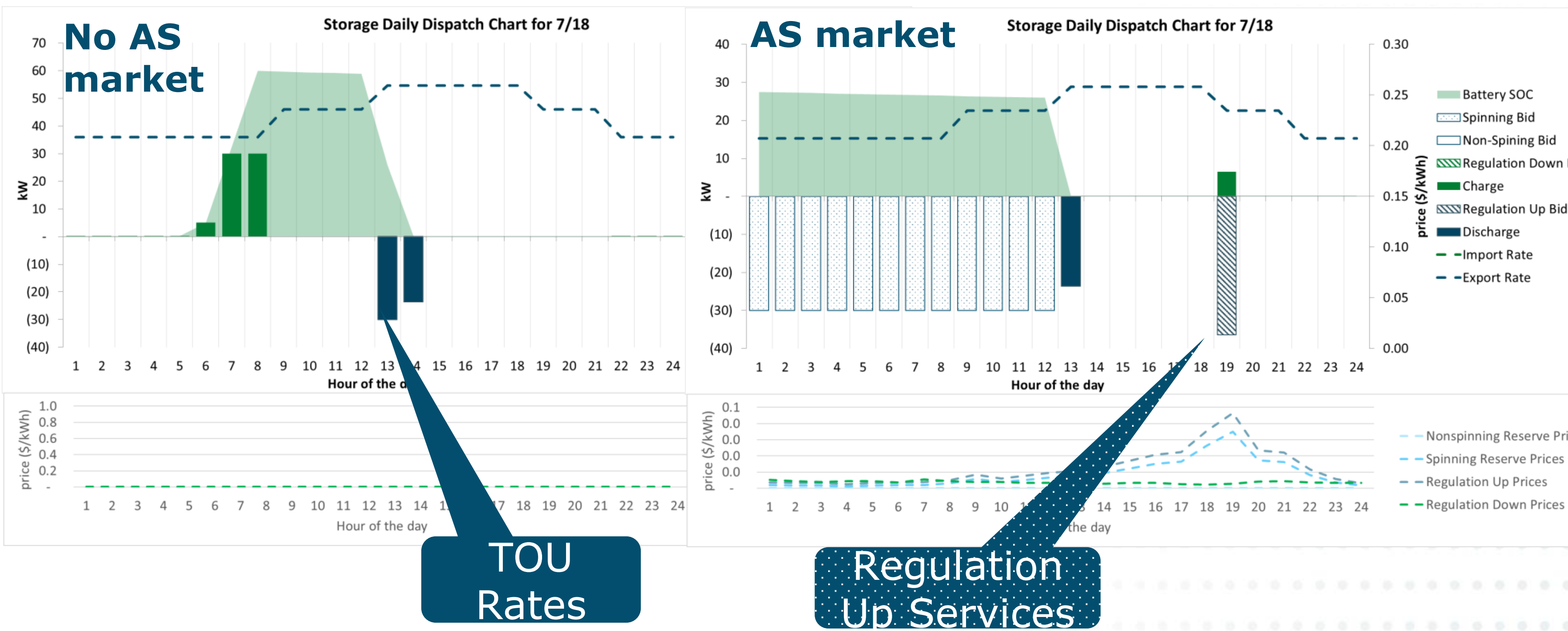




Example Storage Dispatch Chart – TOU rates vs AS services

- Example dispatch chart for an 2-hour 30 kW batteries

Customer Dispatch



Example Storage Dispatch Chart - Demand Charge

+ **Example dispatch chart for an 2-hour 30 kW batteries on a peak day in July**

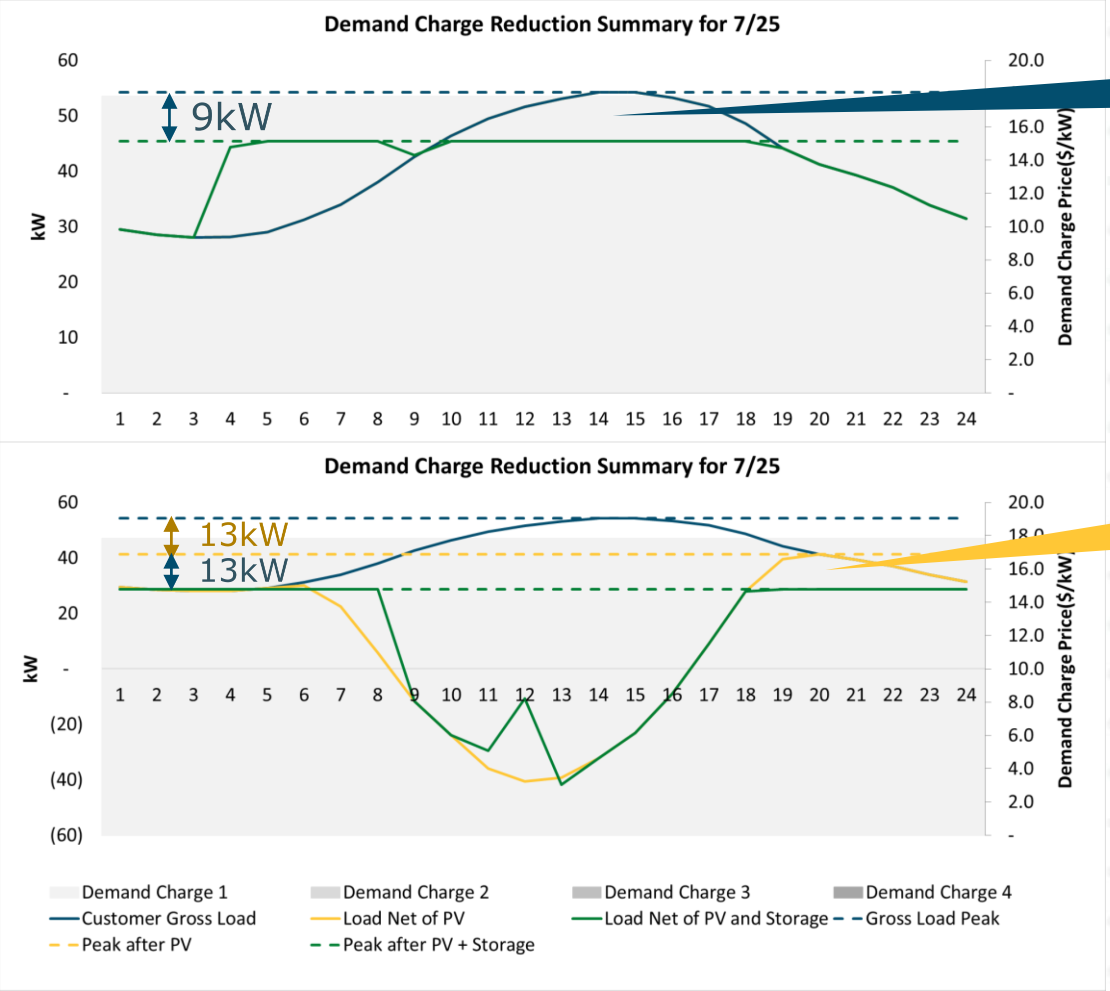
Customer Dispatch

w/o PV

with PV

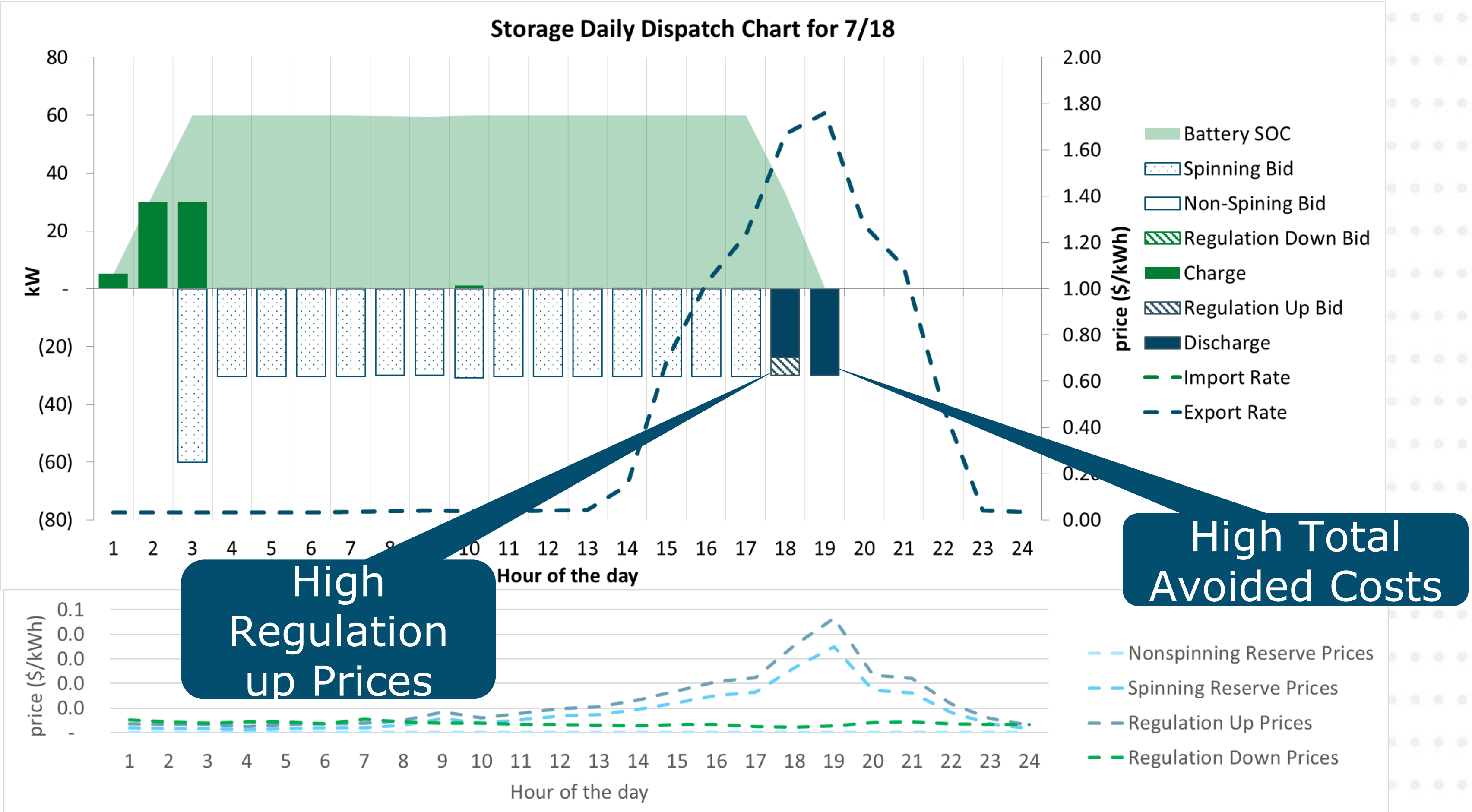
Reduce peak demand

Reduce peak demand

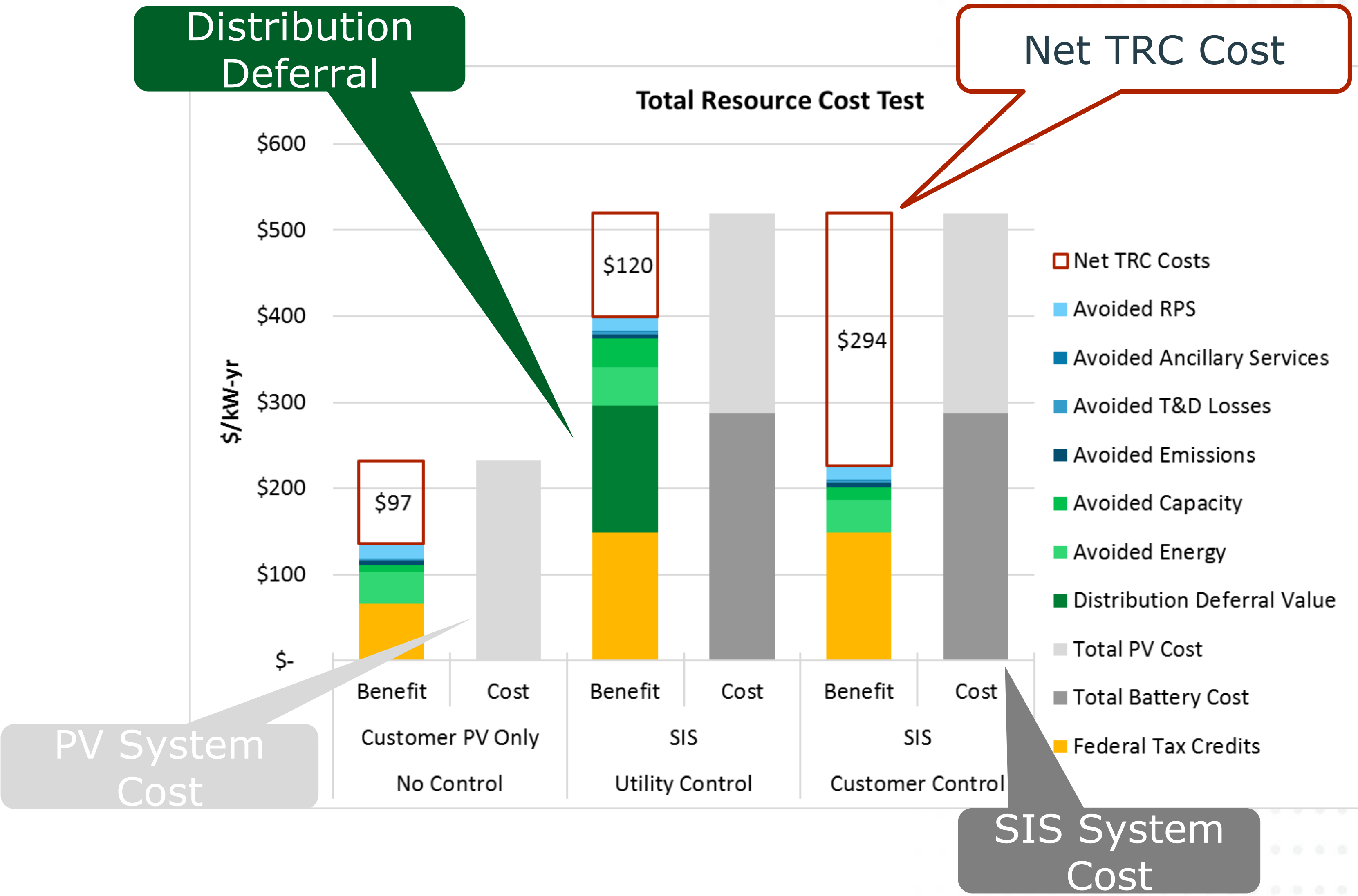


Example Storage Dispatch Chart – Utility Dispatch

Utility Dispatch

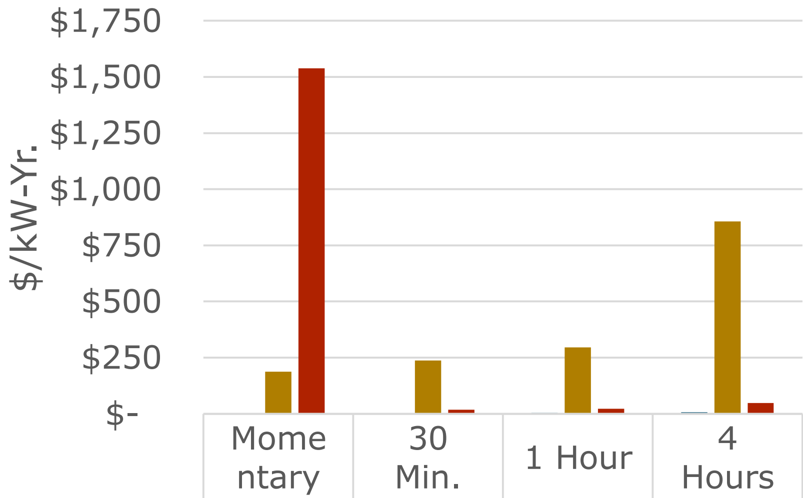


Higher Total Resource Cost Benefits with Utility Dispatch



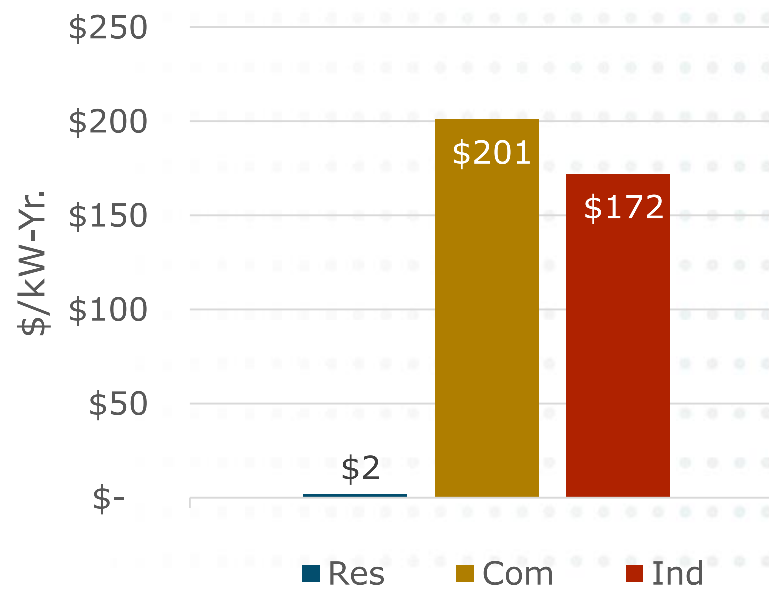
Reliability Value

Outage Cost



	Momentary	30 Min.	1 Hour	4 Hours
Res	$3	$3	$3	$6
Com	$188	$237	$295	$857
Ind	$1,539	$19	$22	$48

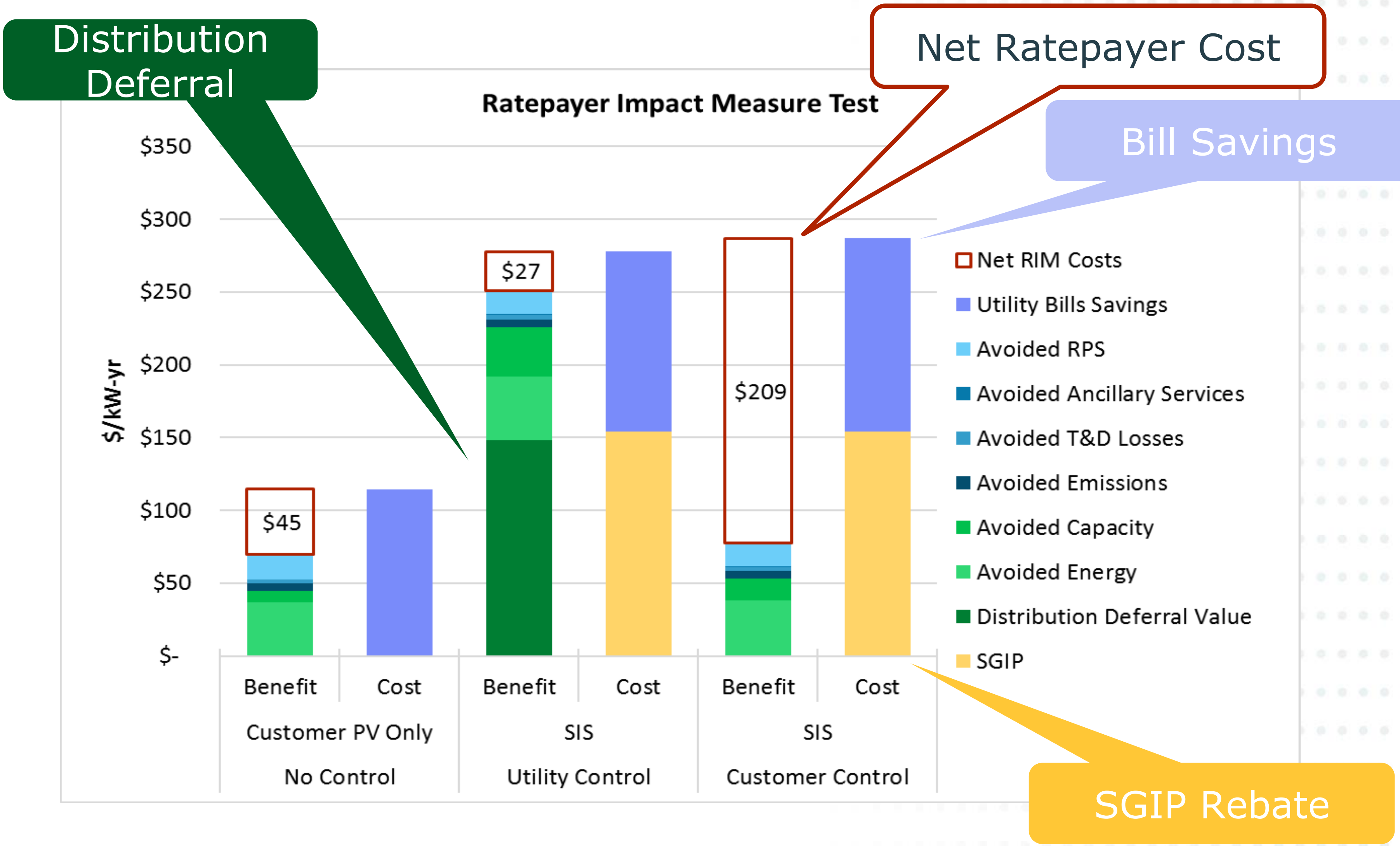
Customer Reliability Value of 2 Hour Battery on SMUD System



Sullivan, M. J., Schellenberg, J., & Blundell, M. (2015). *Updated Value of Service Reliability Estimates for Electricity Utility Customers in the United States.* Lawrence Berkeley National Laboratory. Retrieved from https://emp.lbl.gov/sites/all/files/lbnl-6941e.pdf

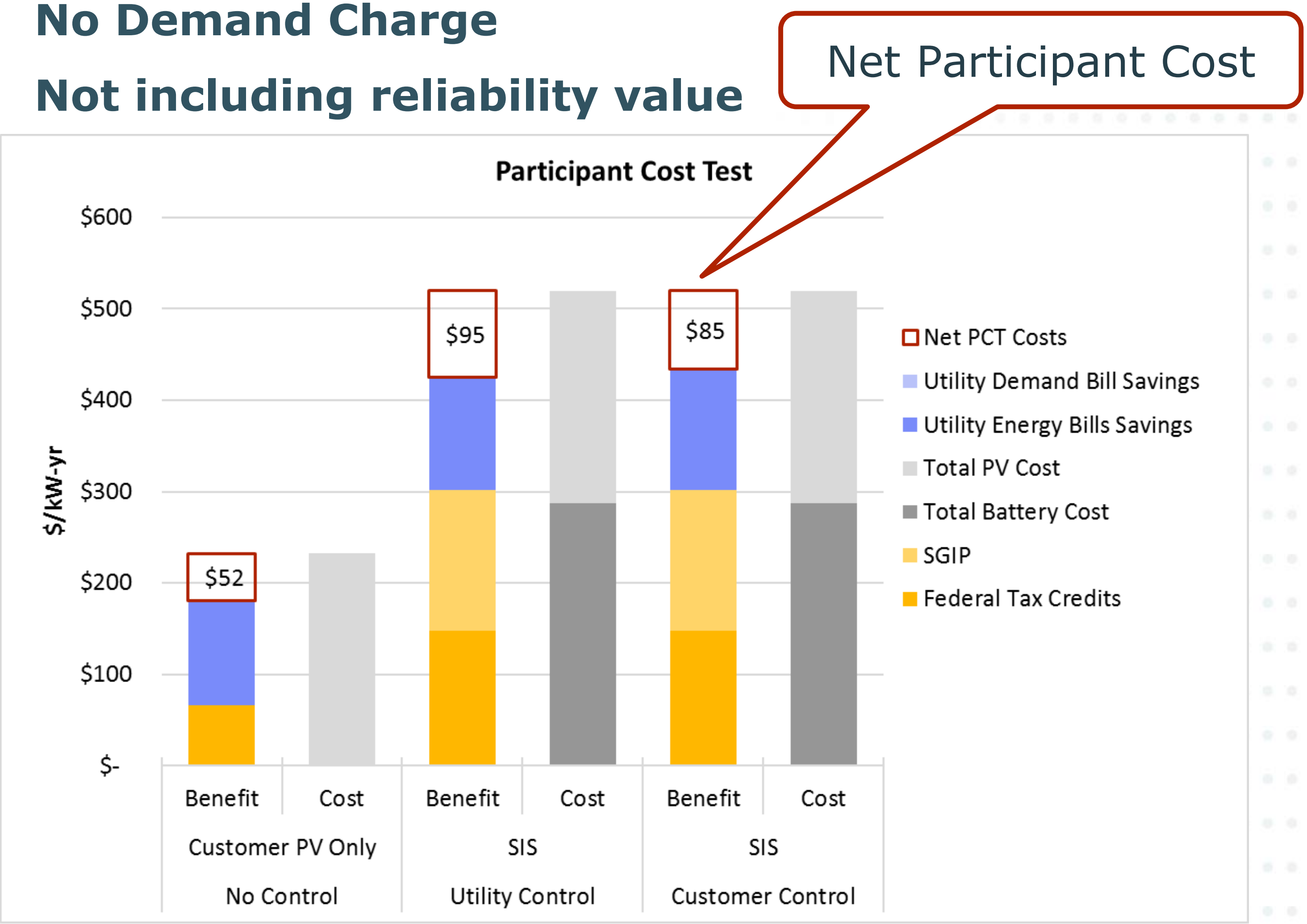
Reliability value <u>not</u> included in TRC calculations presented here

Reduced Ratepayer Cost Shift with Utility Dispatch

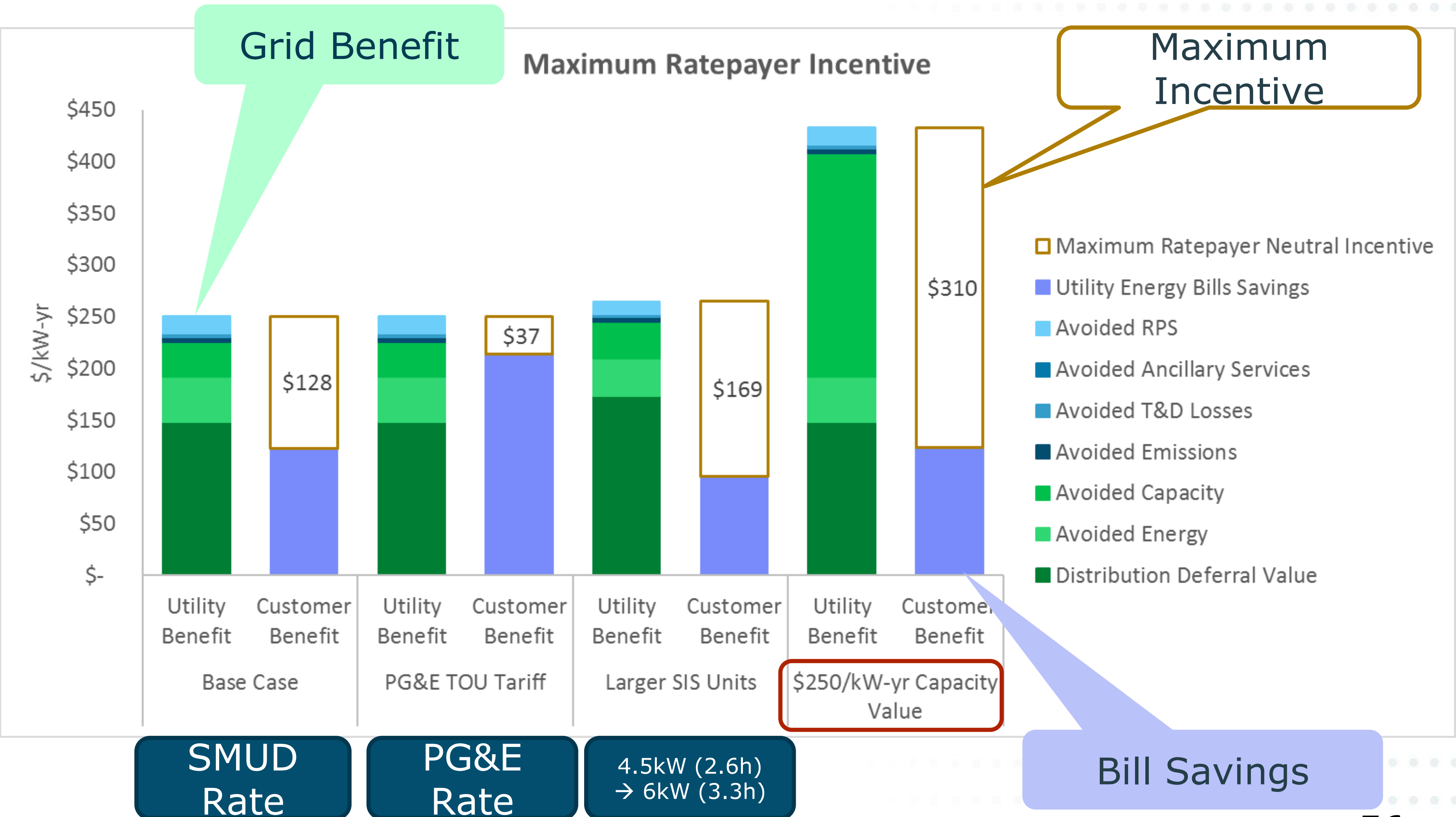


Participant Cost Test– Jackson Sunrise

- Low SMUD Rate
- No Demand Charge
- Not including reliability value



Ratepayer Neutral Incentive – Jackson Sunrise



Conclusions

- TRC Cost-effectiveness is still a challenge for storage, but can be positive with reliability, local capacity and distribution deferral values
- Adding storage increases the NEM cost-shift to non-participating ratepayers (under customer dispatch)
- TRC benefits increase 2.5x with utility dispatch and high deferral value in this case study (eliminating NEM cost-shift)
- TOU and CPP rates do not necessarily align with distribution peak loads
- Incorporating dispatch for utility benefit is technically feasible and significantly increases ratepayer benefits relative to current storage incentive programs

Utility PV Integrated Storage Program Design Framework

August 11, 2016

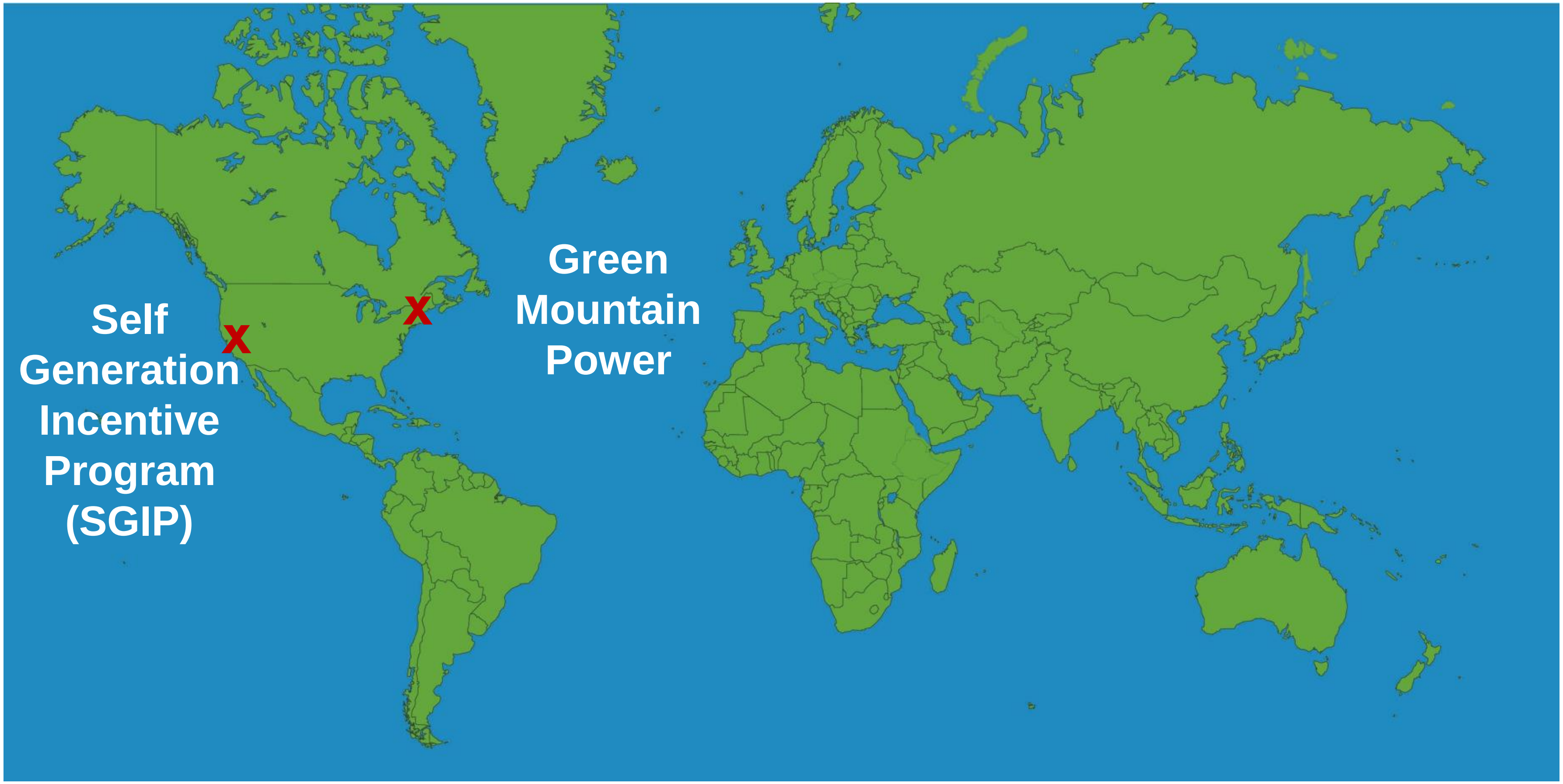
PRESENTED BY

Christine Riker

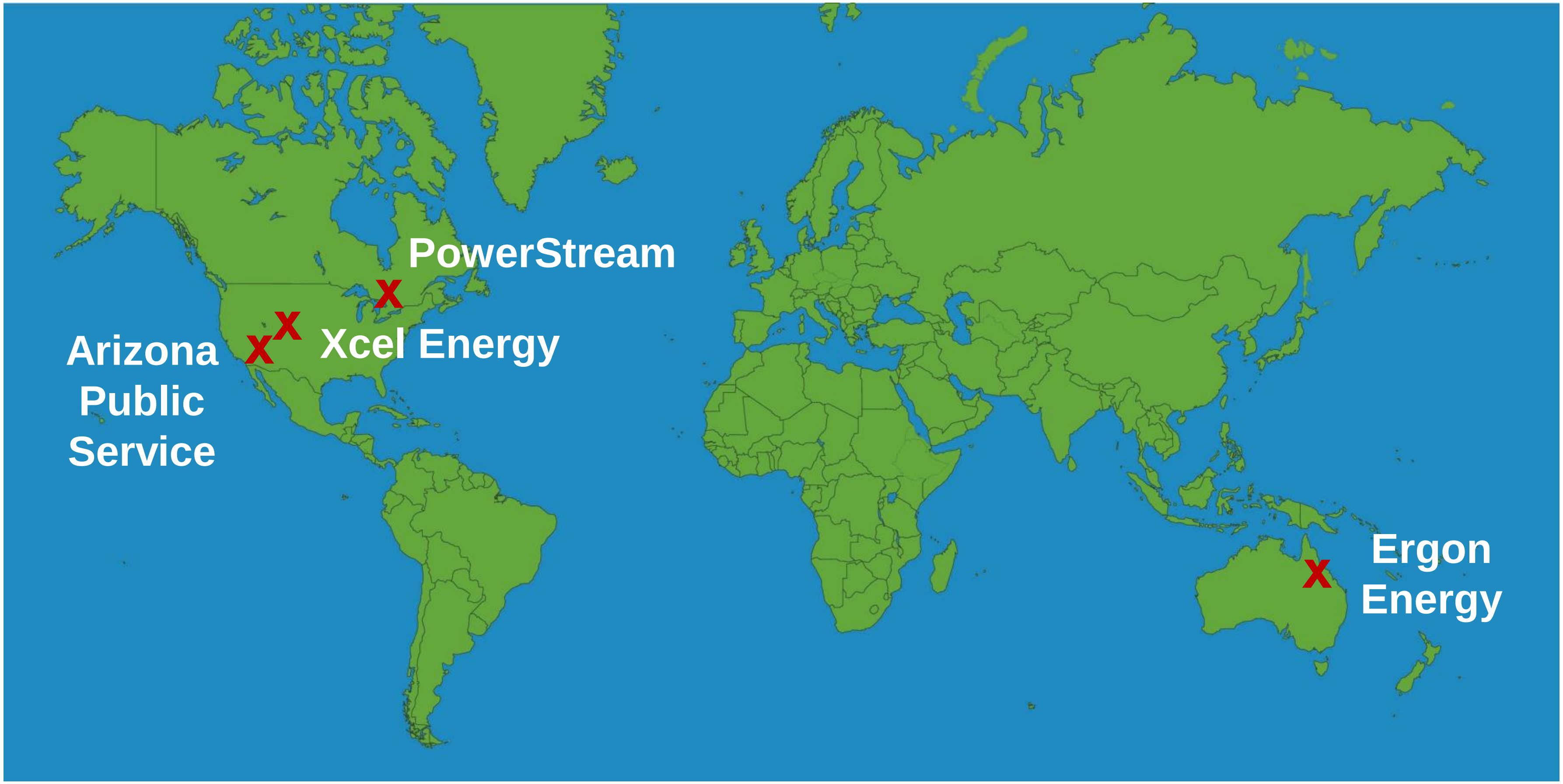
Senior Project Manager

ENERGY SOLUTIONS

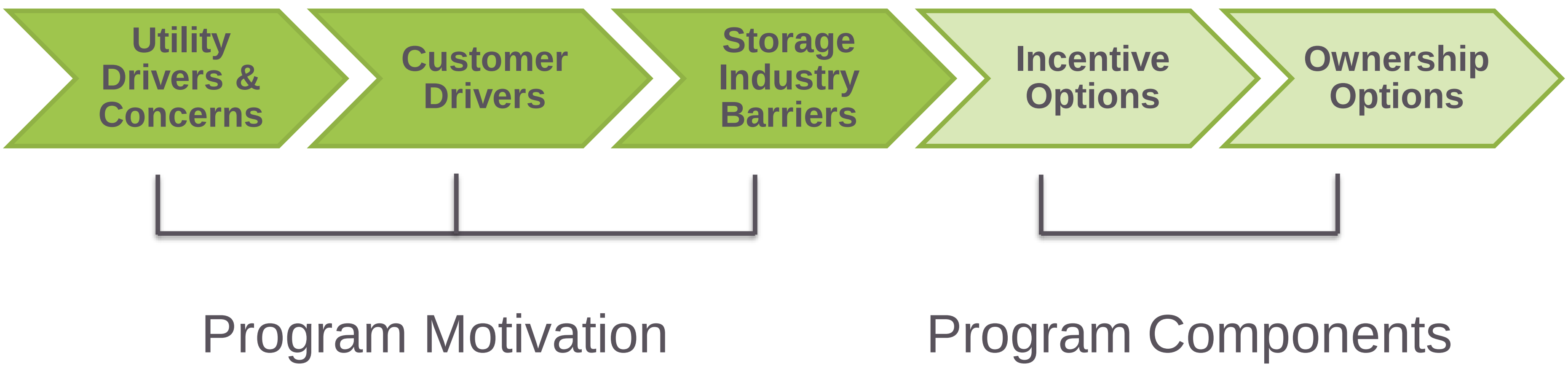
Existing Residential Storage Utility Programs



Existing PV+Storage Utility Pilots



PV Integrated Storage Program Design Framework



Program Motivation: Utility

Utility Drivers

- Regulatory requirements
- Financial benefits
- Support customer transition from lucrative NEM rates
- Trusted customer energy advisor
- Gain industry knowledge

Utility Concerns

- 3rd party interference with utility customer relationship
- Unpredictable system load impacts
- Costly infrastructure upgrades to enable utility control

Program Motivation: Customer

Customer Drivers

- Emergency back-up
- Support grid integration of renewables
- Early adopters wanting new and ‘cool’ technology
- Improve financial payback of PV
- Reduce electricity costs

Program Motivation: Storage Barriers

Storage Industry Barriers

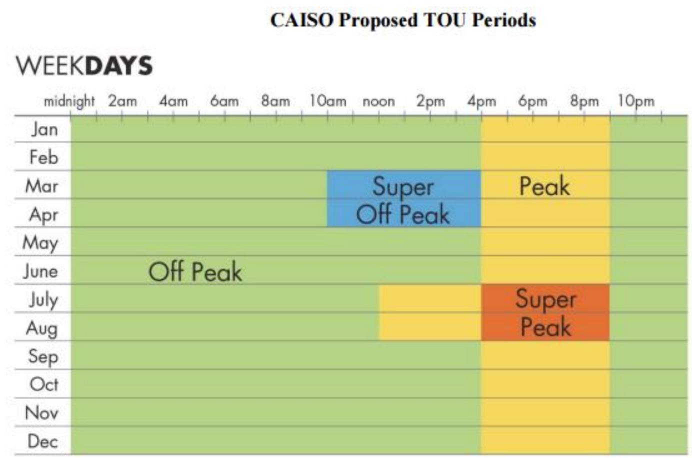
- High first cost
- Inefficiency in interconnection and permitting
- Equipment reliability
- Lack of trained installers

Utility Drivers & Concerns → Customer Drivers → Storage Industry Barriers → Incentive Options → Ownership Options

Program Components: Incentive

Equipment Incentive

Monthly utility payment for control of storage



Electricity Rate

Utility Drivers & Concerns

Customer Drivers

Storage Industry Barriers

Incentive Options

Ownership Options

Program Components: Ownership

Customer owned

Utility owned or leased to customer

Third party owned or leased to customer

Example Program #1: SMUD Case Study

- SMUD Drivers
  - Providing unique value to customer as trusted energy advisors
  - Distribution deferral financial benefits
- SMUD Concerns
  - Unpredictable system load impacts
- Customer Drivers
  - Interest in new and ‘cool’ technology
  - Support grid integration of renewables
- Storage Industry Barriers Addressed
  - Cost

Example Program #1: SMUD Case Study

- **Incentive Options**: Monthly utility payment for control of storage
  - Focused on high value location: Jackson-Sunrise feeder
  - $52/month utility payment

- **Ownership Options**: Customer equipment ownership model
  - Does not introduce third party relationship
  - SMUD does not purchase or maintain systems

Utility Drivers & Concerns

Customer Drivers

Storage Industry Barriers

Incentive Options

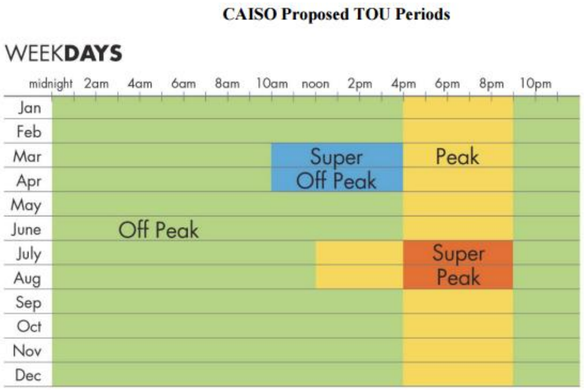
Ownership Options

Example Program #2

- Utility Drivers
  - Reduce utility energy costs through economic dispatch
- Utility Concerns
  - Costly infrastructure upgrades to allow for utility controlled DERs
- Customer Drivers
  - Interest in new and ‘cool’ technology
  - Support grid integration of renewables
- Storage Industry Barriers Addressed
  - Cost

Example Program #2: Midstream

- Equipment incentive for third party providers
  - Utilize electricity rate to enable economic dispatch
  - Utility does not develop infrastructure to manage hundreds of assets



- Allows market to drive change
  - Market decides equipment ownership
  - Marked decides the best way to use the incentive
  - Utility does not pick one technology winner

Example Program #3: Full Value Tariff

1. Customer Charge
   - Fixed $/customer
2. Network Subscription Charge
   - Demand charge $/kW
3. Dynamic Pricing
   - Variable $/kWh

Bill savings (high local T&D value) $/year
Bill savings (zero local T&D value) $/year

New York REV Example

Rate Option	Solar Roof (75% Usage Offset)	Energy Efficient Air Conditioning	Smart HVAC	Battery Storage	Smart Electric Vehicle
Existing Rates	$1,253 / $1,253	$112 / $112	No Savings	No Savings	No Savings
Full Value Tariff or 'Smart' Rate	$1,179 / $742	$146 / $93	$236 / $151	$430 / $305	$141 / $133

THANK YOU

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